GEOPHYSICAL APPLICATIONS FOR RCRA/CERCLA INVESTIGATIONS TASK 4

Ground Penetrating Radar (Landfill)
Rocky Flats Plant

DRAFT REPORT

March 1991

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Ebasco Services

Prepared for:

EG&G ROCKY FLATS, INC.
CONTRACT NO. ASC 37245PB

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EXECUTIVE SUMMARY

EG&G is performing remedial investigations, feasibility studies, and remedial/corrective action projects at the Rocky Flats Plant under the Department of Energy's (DOE) Environmental Restoration Program Previous investigations at the Rocky Flats Operating Landfill have produced a Landfill Closure Plan (Rockwell, 1988) which, in part, encompassed the evaluation of the Operating Landfill groundwater control system The groundwater control system is comprised of two major components; a drainage blanket system designed to intercept and transport groundwater to downgradient ponds, and a soil-bentonite slurry wall designed to prevent shallow groundwater migration into the landfill

Ground Penetrating Radar (GPR) was used in an attempt to delineate individual components of the drainage blanket system and the slurry wall Before the commencement of the GPR program several areas at the Operating Landfill were excavated by Rockwell in an attempt to locate the north and south pipe drain valves and the north and south slurry wall pipe drain modifications The north pipe drain valve was located and unearthed, however, the south pipe drain valve and the north and south slurry wall pipe drain modifications were not located

GPR data acquired at the Operating Landfill correlate with and support the information present in the 'as built' Landfill Engineering Design Drawings. When used in conjunction with the 'as built' drawings, the GPR data provided information on the lateral location of the groundwater control system drainage valves and the slurry wall The GPR data also suggest that the confluence of the groundwater system drainage pipe and slurry wall pipe drain modification on both the north and south sides of the Operating Landfill is further west than previously believed

1 0 INTRODUCTION

A ground penetrating radar (GPR) survey was conducted at the Rocky Flats Plant Operating Landfill as part of Subtask 4 to·

- Delineate the existing groundwater control system, drain and slurry wall location

- Locate pipe drain modifications and discharge valves

- Provide qualitative information on the construction of the groundwater intercept system and slurry wall.

1 1 GPR Technique

GPR is a geophysical technique that consists of transmitting short wavelength (high frequency) electromagnetic waves into the earth and recording those waves reflected back by media that possess contrasts in electrical properties. The GPR record is often displayed as a distance (horizontal) versus time (vertical) plot and can be recorded digitally to allow for post-acquisition processing. Although the GPR record is a complex composition of interference patterns and reflections, its 'picture-like' display makes it relatively easy to interpret. The depth of radar investigation is generally quite shallow due to the high frequencies utilized, however, this disadvantage is partially offset by the increased resolution it offers over other geophysical techniques

The detection of an object by GPR depends primarily upon the electrical properties of the host and target materials. The electrical properties of the subsurface which influence GPR are the dielectric permittivity, conductivity, and magnetic permeability. Moisture, certain types of clays with high cation exchange capacities (CEC), and other conductive material(s) can severely restrict or even preclude penetration of the radar pulse

2 0 GROUNDWATER CONTROL SYSTEM

A groundwater control system was constructed at the Operating Landfill in 1974 and updated in 1982. The groundwater control system at the Operating Landfill consists of two components (Figure 1). The primary component is a blanket drain system keyed into existing bedrock and designed to intercept and transport shallow uncontaminated groundwater flow to ponds downgradient of the Operating Landfill (Rockwell 1988). The blanket drain system was constructed in 1974 and is located at a depth of approximately 20 ft (Rockwell, 1988) The second component of the groundwater control system is a soil-bentonite slurry wall constructed in 1982 to prevent shallow groundwater migration into the Operating Landfill. The soil-bentonite slurry wall was integrated with the blanket drain system at the pipe drain modification locations (Appendix C, Sheet 6). The bottom of the slurry wall was positioned at a depth of approximately 15 to 20 ft, and the top of the slurry wall was situated a minimum of 2 ft under the ground surface (Rockwell, 1988).

The landfill was extended sometime after 1974 to include the blanket drain system trench The blanket drain system drainage pipes that were designed to intercept groundwater flow may have collected landfill leachate, which rendered the blanket drainage system only partially effective Additionally, the blanket drain system contains several discharge valves (Figure 1). The operating position and structural condition of the discharge valves is not known at the present time. If the discharge valves are closed and/or not functioning properly, the water and leachate collected by the blanket drain system may be impounded in certain areas within the landfill (Rockwell, 1988).

EBASCO recently discovered that at least two sets of Landfill Engineering Design Drawings are in existence at the Rocky Flats Plant. The Landfill Engineering Design Drawings present in the Landfill Closure Plan are specified as 'original issue' and differ from the Landfill Engineering Design Drawings specified as 'as built' and included in Appendix C of this report.

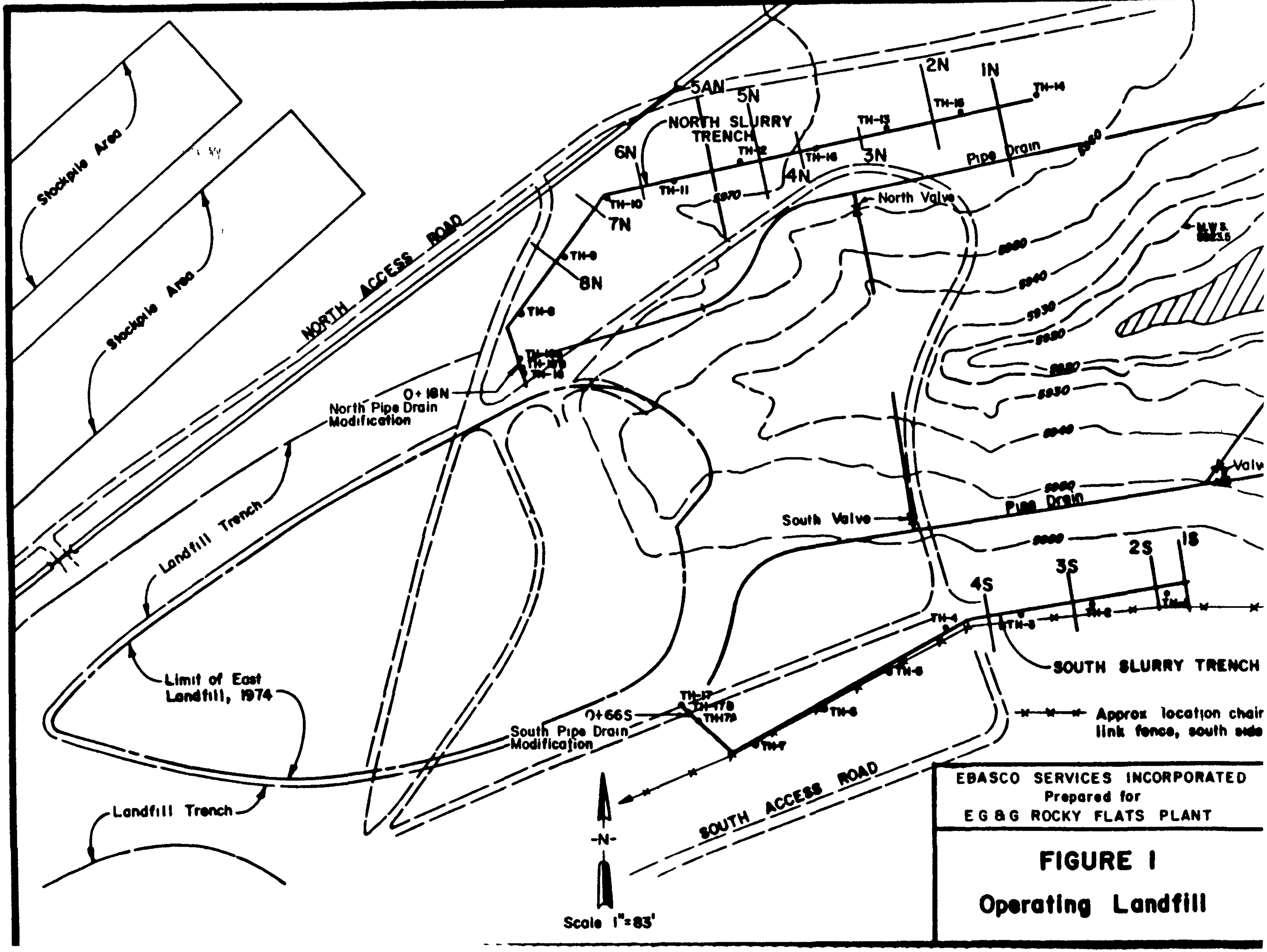

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FIGURE I
Operating Landfill

3 0 DATA ACQUISITION

The GPR survey lines were established at the Operating Landfill using a a measuring tape. The GPR profile lines were positioned in an attempt to delineate both the slurry wall and groundwater control system Due to severe topography and current landfill disposal practices, it was not possible to position the GPR survey lines to define both the slurry wall and groundwater control system at some locations

The south slurry wall is 900 ft long Four GPR profiles were acquired perpendicular to the slurry wall from slurry station 9 + 00 to 5 + 80 (Figure 1). The south slurry wall was not investigated from slurry station 5 + 80 to 1 + 68 due to the close proximity of a chain-link fence to the slurry wall Interfering reflections from the fence were evident on the GPR records and prevented the detection of the slurry wall in this area. Data were acquired in a south to north direction on all profiles

The north slurry wall is approximately 1,000 ft long Nine GPR profiles were acquired perpendicular to the slurry wall from slurry station 10 + 00 to 0 + 75 (Figure 1). Current landfill disposal activities prevented the acquisition of GPR data in some areas between slurry stations 6 + 00 to 3 + 50. All lines were traversed from north to south with the GPR antenna except Lines 3N and 5AN, which were performed in a south to north direction

3 1 Equipment

The Rocky Flats Operating Landfill GPR survey was conducted using a digitally equipped Subsurface Interface Radar (SIR) 3 system. The unit consists of a graphic recorder, analog to digital module, tape recorder, color monitor, cables and an antenna. Common antenna frequencies range from 50 megahertz (MHz) to 1 gigahertz (GHz), with lower frequency antennas employed when maximum depth penetration is needed. The antenna chosen for the Rocky Flats Operating Landfill GPR survey was the GSSI 3112, which emits a broad band of frequencies and is characterized by its center frequency of 80 MHz. The 80 MHz antenna is unshielded (i e , radiates energy in all directions) and as a consequence, above - ground cultural features such as fences, power lines, and tree branches can appear as prominent reflections on the GPR record. Special care must be taken when interpreting GPR data acquired with an unshielded antenna to discount above ground cultural noise

4 0 DATA ANALYSIS AND INTERPRETATION

Interpreted and uninterpreted radar sections are presented in Appendix A and Appendix B, respectively The GPR interpretation at the Operating Landfill was complicated by the presence of surface and subsurface moisture, clays, boulders, concrete blocks, asphalt, severe topography, and landfill debris. The GPR field acquisition parameters were designed to detect the groundwater intercept system and slurry wall as they were originally designed (Figure 2). However, these construction methods cannot be verified because as- built documents are not available (Rockwell, 1988).

4 1 GPR Model

A GPR model was constructed using the geometries in Figure 2. The relative dielectric permittivity (Er) and conductivity (0) of the model components were estimated as follows

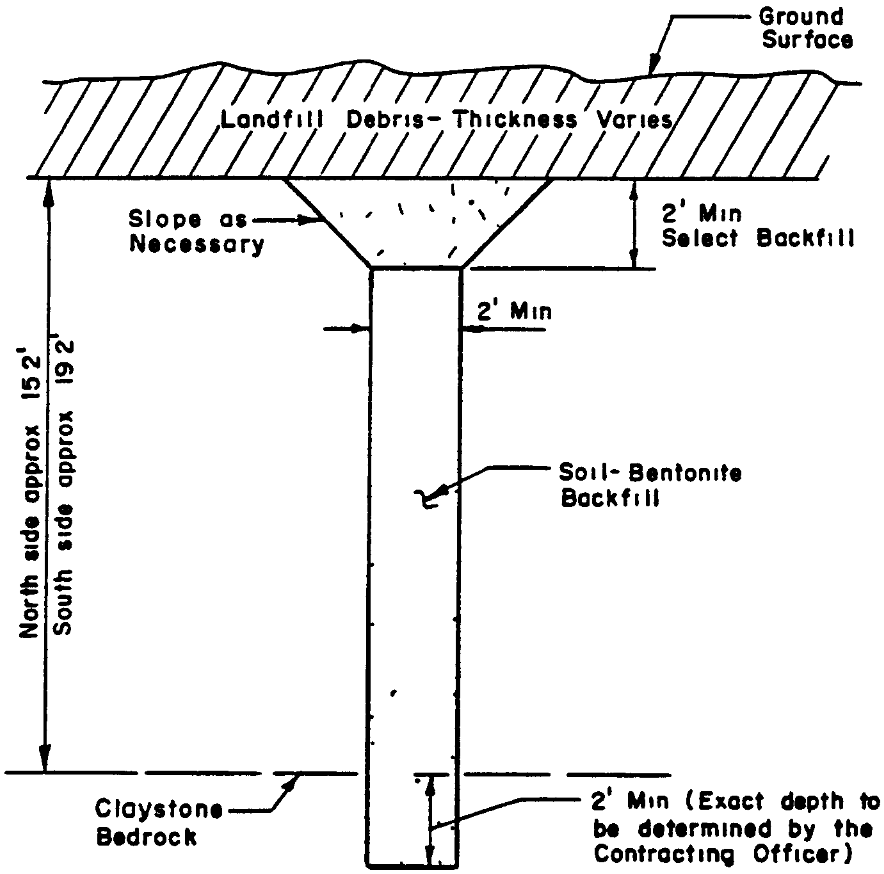
	Er	O (mmhos/m)
Landfill debris and soil	8-10	40-50
Alluvium	4-6	30-40
Soil-bentonite mixture	10-13	70-80

References· Ulriksen, 1981, Daniels, 1989.

The GPR model, although simplistic, provided relevant information that was used in the interpretation of field data. The model parameters suggest that when the landfill debris/soil and alluvium contain a significant amount of moisture, the penetration of the radar pulse is approximately 1 to 2 ft. When the landfill debris/soil and alluvium are relatively dry, the penetration of the radar pulse is approximately 6 to 8 ft

4.2 Interpretation

Two velocity tests conducted at the Operating Landfill provided a time-depth relationship to assist in the interpretation of the GPR records A GPR velocity test consists of traversing the antenna over an object (reflector) with a known depth and recording the travel time of the reflected wave Based on the travel time of the reflected wave it is possible to estimate the depth



TYPICAL SLURRY TRENCH DETAIL

NOT TO SCALE

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FIGURE 2

Slurry Trench

of the reflecting object The velocity tests suggest the depth penetration of the radar pulse is approximately 4 to 5 feet on most of the GPR records. Since the groundwater intercept drainage system and associated piping are located at a depth of approximately 20 ft (Rockwell, 1988), the GPR interpretation strategy was restricted to near- surface radar anomalies that might be representative of excavation, changes in soil (backfill) type and moisture, compaction characteristics, and subsidence.

There may be an interpretable relationship between the slurry wall construction and the surrounding soil. The change in soil type and character between the slurry wall and surrounding soil produces a characteristic reflection on some of the GPR records (Appendix A). The reflection cannot be seen on the entire suite of radar profiles, most likely due to the following factors:

- Increased landfill overburden (trash) thickness in some areas precludes further radar signal penetration

- Small landfill objects scatter the radar signal, preventing a detectable response from the slurry wall

- Increased soil moisture and clay content in some areas prevent the radar signal penetration necessary to define the slurry wall.

At the Operating Landfill, debris has been continually placed on top of the groundwater intercept system and slurry wall. Where the debris thickness exceeds 3 to 4 feet there is a very low probability of detecting the slurry wall with GPR.

The area encompassing GPR lines 4N, 5N, 5AN, 6N, 7N, and 8N was disturbed by landfill disposal activities during the period of the GPR survey. It was observed during field activities that this area of the landfill exhibits standing water at the surface after heavy rains. The increased near-surface moisture content, coupled with recent soil disturbance and debris disposal, may have prevented the detection of the slurry wall by GPR in some of these areas The radar records of lines 6N, 7N, and 8N exhibit increased attenuation of the radar signal, making it difficult to interpret the location of the slurry wall.

The groundwater intercept drainage system pipe drain modifications (Appendix C, Sheet 6) exist at a depth of approximately 15 to 20 ft near North Slurry Trench station 0 + 18 and South Slurry Trench station 0 + 66 (Figure 1) The pipe drain modifications were not located with the GPR system due to severe topography and a burial depth of approximately 15 to 20 ft. The respective lateral locations of the pipe drain modifications were interpreted by using GPR data from the Operating Landfill GPR survey and integrating the GPR data with the Operating Landfill Extension Site Plan, Drawing Number 27915-003 Sheet 3 (Appendix C) The slurry wall produces a characteristic reflection on some of the GPR records, and these reflector locations were integrated with known features present on the Operating Landfill Extension Site Plan blueprints (boring locations, test pits, and test holes) to infer the pipe drain modification and valve locations A set of Operating Landfill Extension site plan blueprints have been included in Appendix C. The interpreted pipe drain modifications, as well as the slurry wall and valve locations were staked in the field by EBASCO However, these stakes have been disturbed and/or destroyed by landfill disposal activities in the recent past, and their locations should be surveyed as soon as possible by EG&G personnel As of March 29, 1991, EBASCO field personnel have verified the correct position of the stakes. The stakes are 1 ft in length and marked with blue survey tape

4.2 1 South Slurry Wall

LINE 1S (Figure 3 and 16)

The antenna was adjacent to the chain-link landfill boundary fence at station 0. The reflection from the fence can be identified on the radar section as a dipping reflector from stations 2 through 15 at an approximate depth of 2.5 ft. The effect of the fence can be seen vertically through the record from between stations 0 and 15 at a depth of approximately 2 ft. The depression on the profile near station 20 at a depth of 2.5 to 3 ft most likely corresponds to the slurry trench.

LINE 2S (Figures 4 and 17)

Noise from the chain-link fence appears on the GPR record from stations 0 to 10 at approximately 3 ft. The slurry wall appears to be located at station 15 at approximately 2.5 to 3 ft in depth. The reflector at station 25 exhibits 'ringing' vertically through the radar section and can be traced to its origin very near the surface This reflector is probably associated with near-surface landfill debris .

LINE 3S (Figures 5 and 18)

Noise from the chain-link fence can be identified on the GPR record from stations 0 to 15 at approximately 2 5 ft The slurry wall is most likely near station 22 at an approximate depth of 2 5 ft.

LINE 4S (Figures 6 and 19)

Noise from the chain-link fence can be identified from stations 0 to 15 at approximately 2 5 ft The slurry wall is most likely located near station 25 at approximately 1 75 ft

4.2 2 North Slurry Wall

LINE 1N (Figures 7 and 20)

The slurry trench is evident at station 37 at approximately 2.5 ft. The subsurface character of the entire profile exhibits compacted soil horizons with disturbed, uneven surfaces due to compacted layers in the landfill

LINE 2N (Figures 8 and 21)

Line 2N, which exhibits the same general character as Line 1N, is in the vicinity of the asbestos disposal area The slurry wall is most likely at station 50, at an approximate depth of 2 to 2.5 ft. Profiling on Line 2N commenced adjacent to the chain-link fence, consequently its effect can be identified on the GPR record from stations 0 to 15 at approximately 3 ft. The reflector near station 55, at approximately 2 to 2.5 ft, in depth is most likely isolated landfill debris

LINE 3N (Figures 9 and 22)

Line 3N was traversed in a south-to-north direction The slurry wall is evident at station 3 at approximately 2.5 ft in depth The reflector near station 9 at approximately 2 ft in depth may be a small depression generated during landfill disposal practices

LINE 4N (Figures 10 and 23)

The GPR record exhibits a rough surface and possible landfill debris to approximately 4 ft in depth. The slurry wall may be at station 20 at approximately 3 ft in depth. Other reflectors on the profile can be traced to near-surface origins

LINE 5N (Figures 11 and 24)

There are several interesting reflectors on the GPR profile The hyperbolic reflector at station 23 at a depth of approximately 2 ft exhibits symmetry, and may be indicative of a cylindrical object The soil disturbances evident between stations 45 and 60 at approximately 2.5 ft in depth are most likely related to trenching, compaction, and subsidence of material in the landfill. The slurry wall is difficult to define on GPR record 5N, but may be located near station 40 at approximately 2 ft in depth

LINE 5AN (Figures 12 and 25)

The slurry wall is most likely at station 60 at approximately 2 ft in depth. Other reflectors on the GPR record, such as the thin hyperbolic reflector near station 35, can be traced to near-surface origins

LINE 6N (Figures 13 and 26)

The GPR record exhibits a rutted, uneven surface caused by recent landfill operations A subtle hyperbolic reflector near station 18, at approximately 2 ft in depth, may be the subsurface expression of the slurry wall, however, it also may be an isolated landfill reflector (i e., concrete block, small pipe, wood, etc).

LINE 7N (Figures 14 and 27)

GPR record 7N exhibits similar character to Line 6N. The slurry wall may be at station 20 at approximately 3 ft in depth.

LINE 8N (Figures 15 and 28)

GPR record 8N exhibits a disturbed near-surface due to recent landfill operations The slurry wall may be near station 20 at an approximate depth of 2 5 to 3 ft

5.0 CONCLUSIONS AND RECOMMENDATIONS

The Operating Landfill GPR survey was successful in delineating the slurry wall at many locations and providing relevant information as to the location of the groundwater intercept drainage system and its associated discharge valves The GPR data indicate the slurry wall to be present on GPR profiles 2S, 3S, 4S, 2N, 3N and 5AN. GPR profiling of Lines 4N, 5N, 6N, 7N, and 8N was hindered by landfill disposal operations during the GPR survey. Increased near-surface moisture content may have also had an adverse effect on the data acquisition on Lines 4N, 5N, 6N, 7N, and 8N. Therefore, interpretation of the slurry wall location on these GPR profiles was difficult.

Based on the success of the GPR method at the Operating Landfill, GPR may exhibit potential at the Rocky Flats Plant in both geotechnical and geological applications.

Geotechnical applications include.

- Subsurface utility location and assessment
- Solar ponds french drain system location and assessment.

Geological applications include

- Shallow structural and stratigraphic analysis on existing seismic lines
- Borehole radar for cross-hole tomography

Although the GPR signal penetration was limited at the Operating Landfill because of the abundance of cultural debris and near-surface moisture, there is potential to achieve increased penetration of the GPR signal in non disturbed areas of the Rocky Flats Plant.

REFERENCES

Daniels, J. (1989), Fundamentals of Ground Penetrating Radar, SAGEEP 1989 Proceedings

Rockwell (1989), Landfill Closure Plan

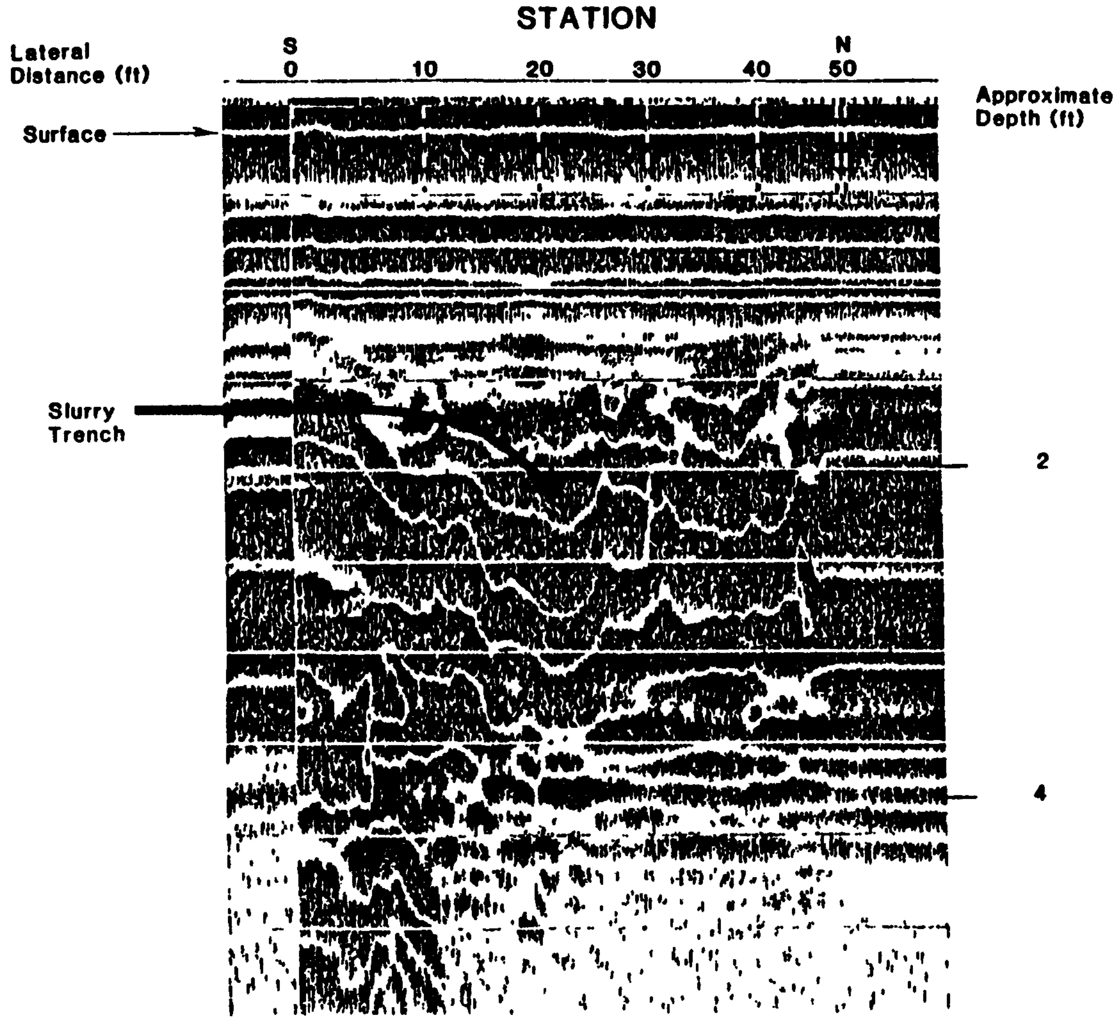
Ulriksen, P (1981), Application of Impulse Radar to Civil Engineering

APPENDIX A
Interpreted GPR Profiles

TABLE A-1

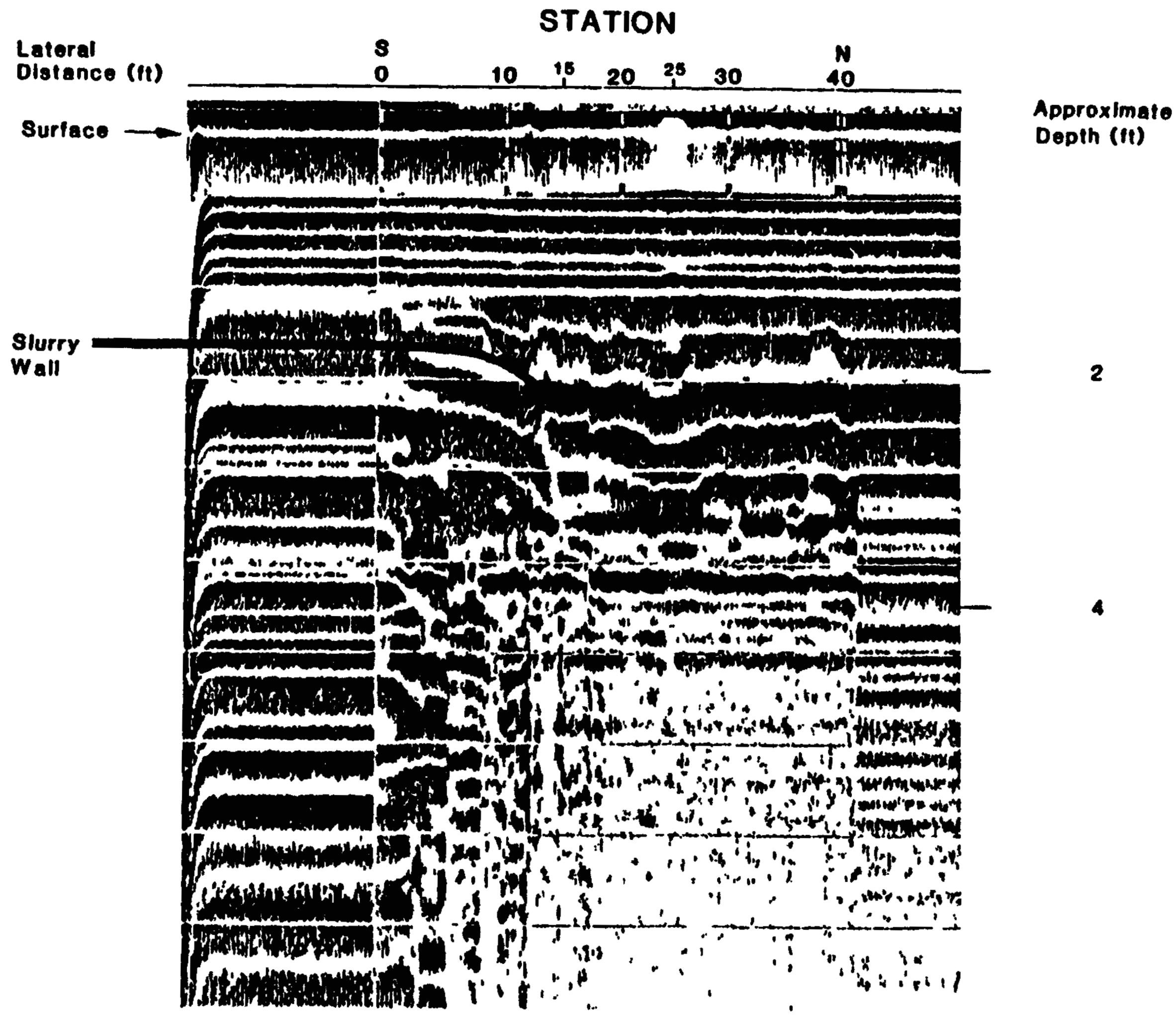
DATA ACQUISITION PARAMETERS FOR THE GPR SURVEY

Antenna	80 MHz monostatic
Print Recorder Parameters	
Print Polarity	Plus and Minus
Lines/inch	100 to 200
Scans/Second	16
Transmit Rate	50 kHz
Amplifier Parameters.	
Gain	Automatic Gain Control (AGC)
Range	50 to 100 nanoseconds (ns)
Threshold	50 percent
Low Pass Filter	50 cycles/second
High Pass Filter	10 cycles/second
Signal Position	Automatic



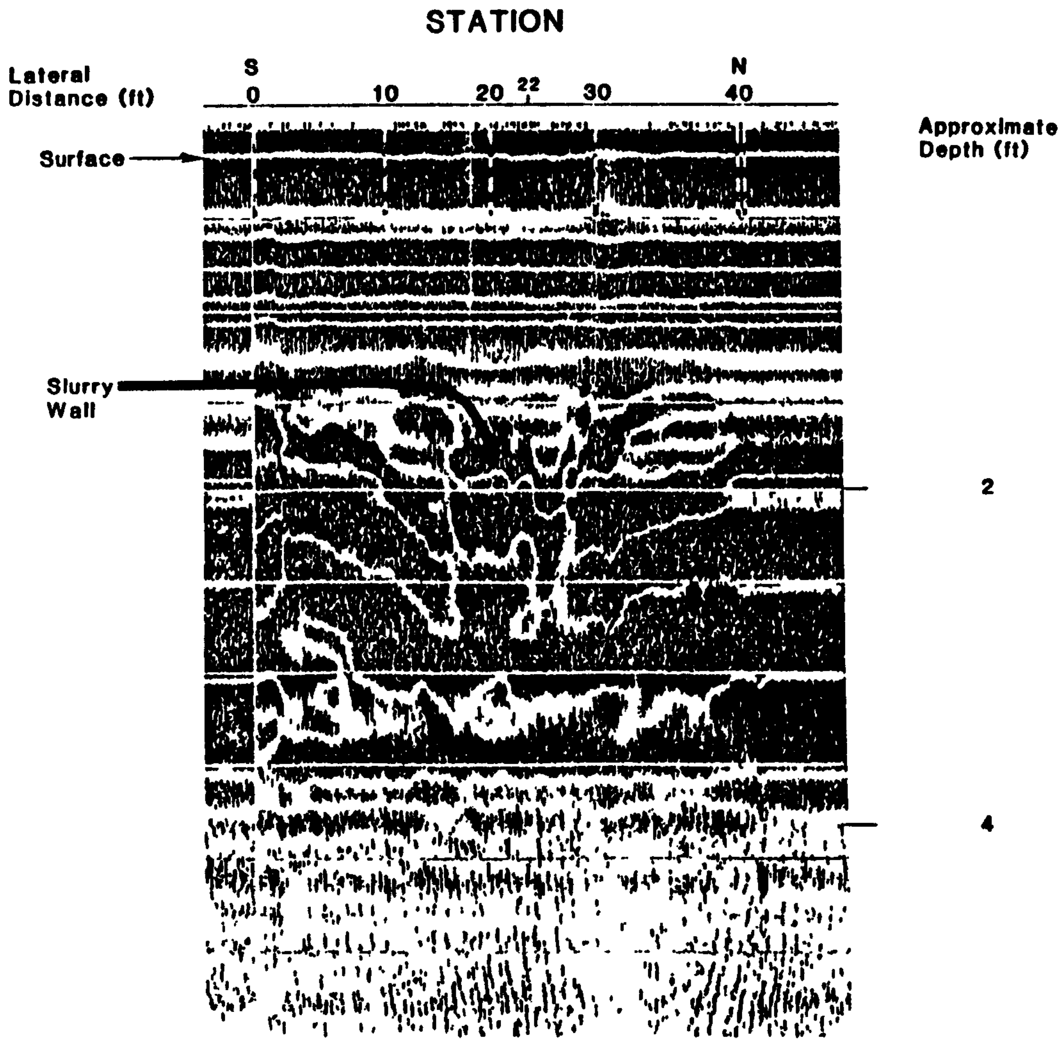
Line 1S

FIGURE 3

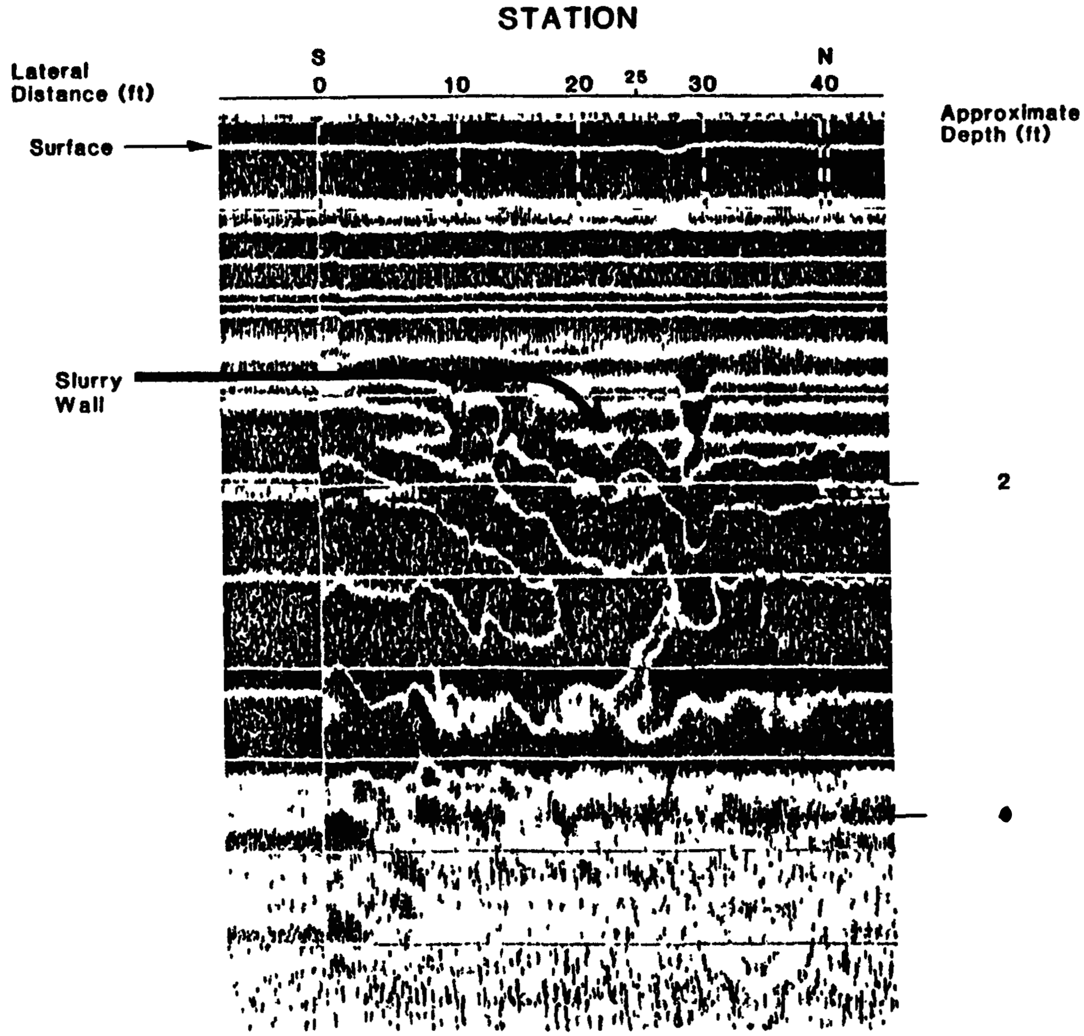


Line 2S

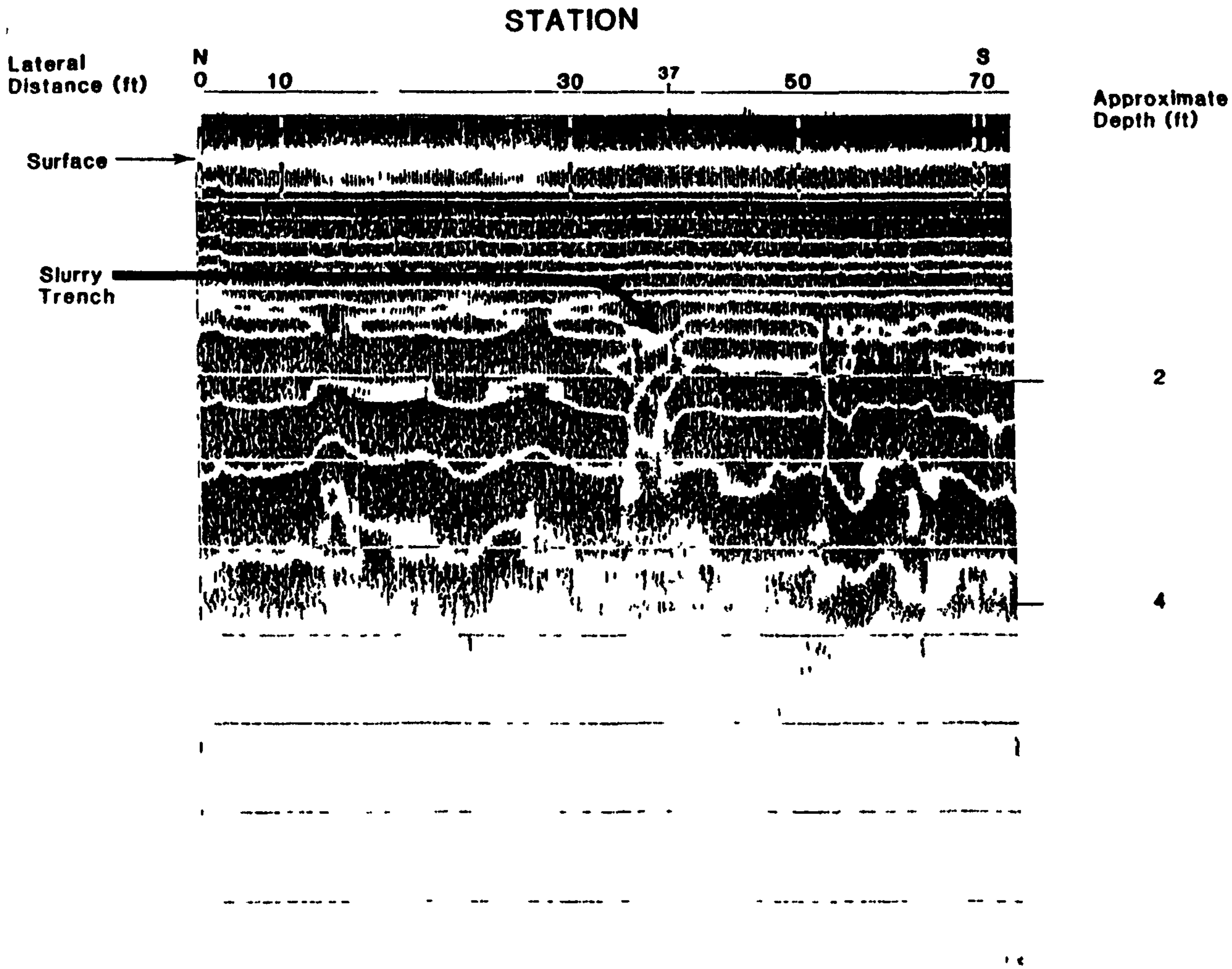
FIGURE 4


STATION
Lateral
Distance (ft)
S
0
10
20
22
30
N
40
Surface
Slurry
Wall
Approximate
Depth (ft)
2
4

Line 3S

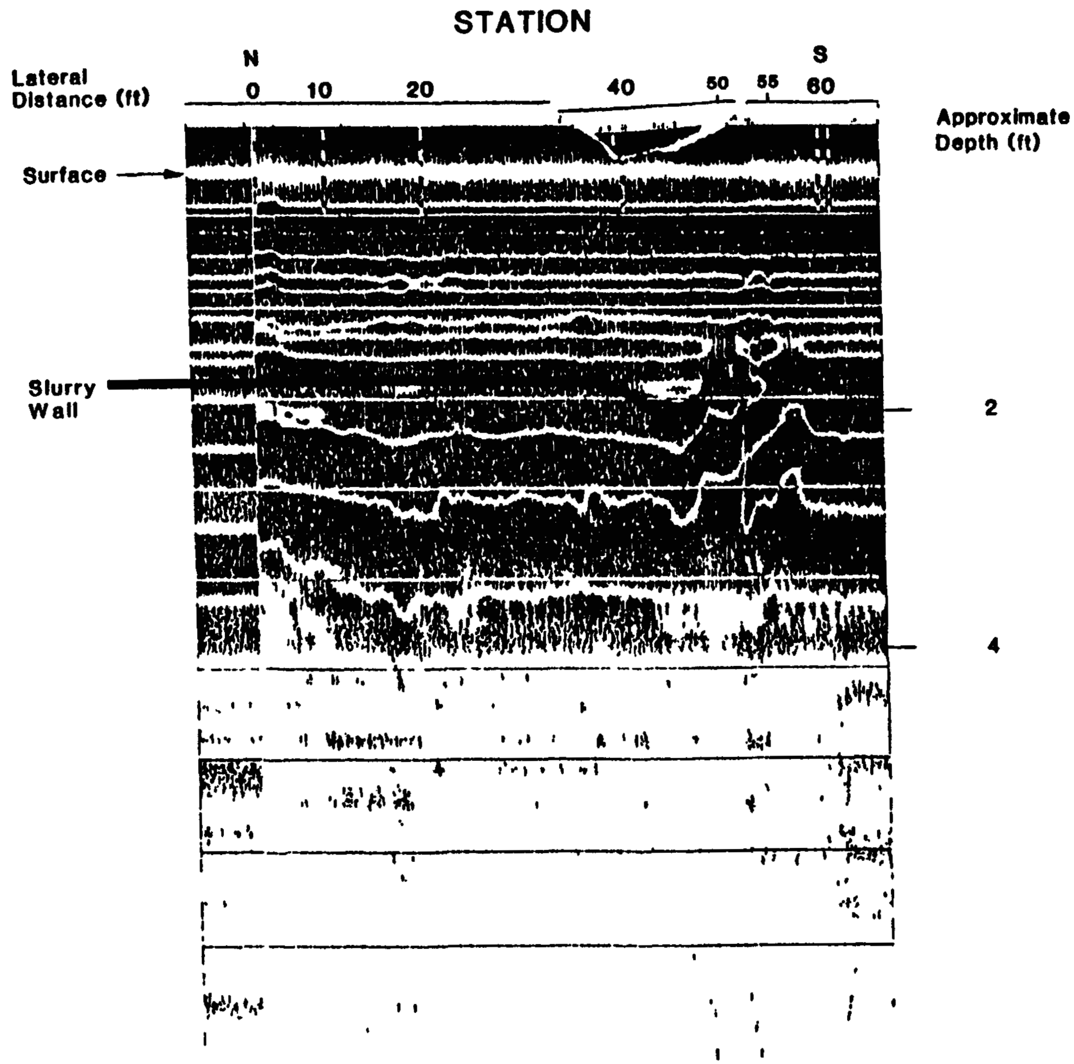

STATION
S
N
0
10
20
25
30
40
Lateral Distance (ft)
Surface
Slurry Wall
Approximate Depth (ft)
2

Line 4S



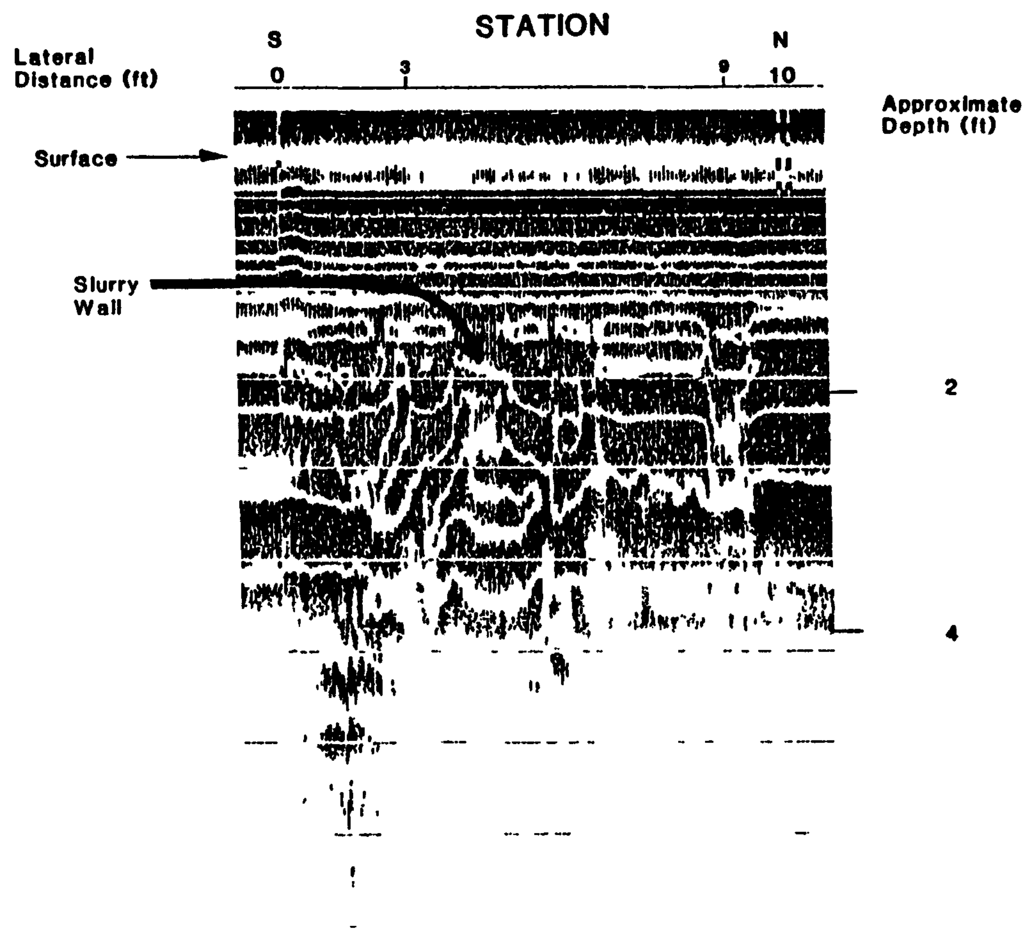
Line 1N

FIGURE 7



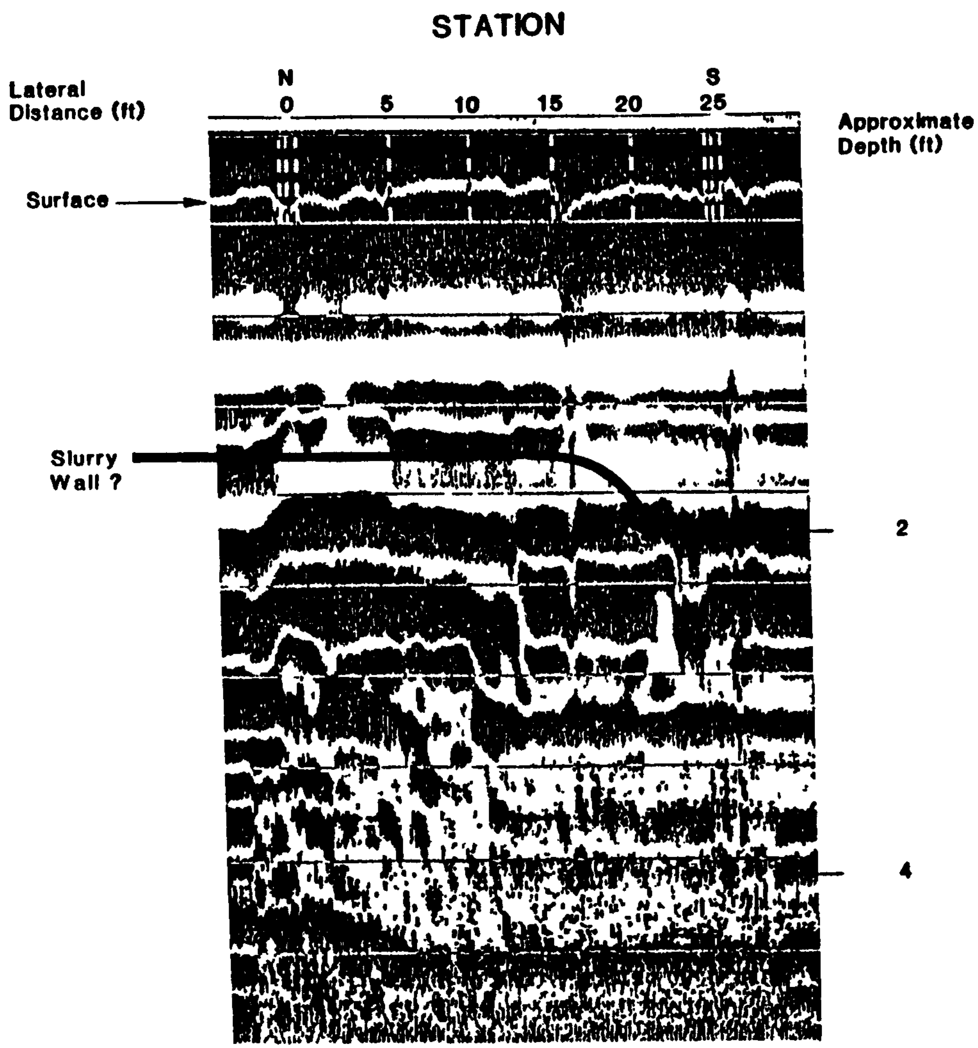
Line 2N

FIGURE 9

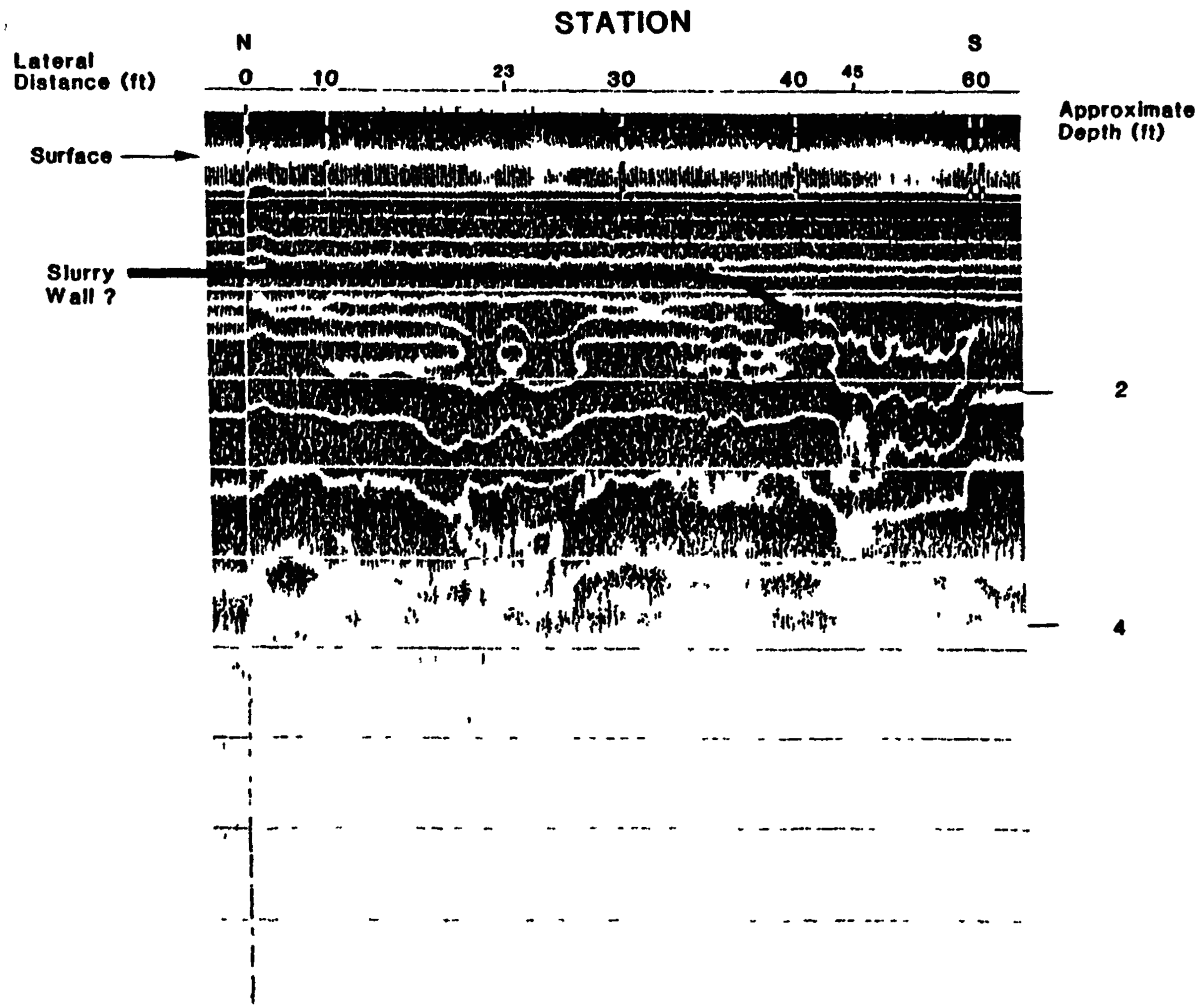


Line 3N

FIGURE 9

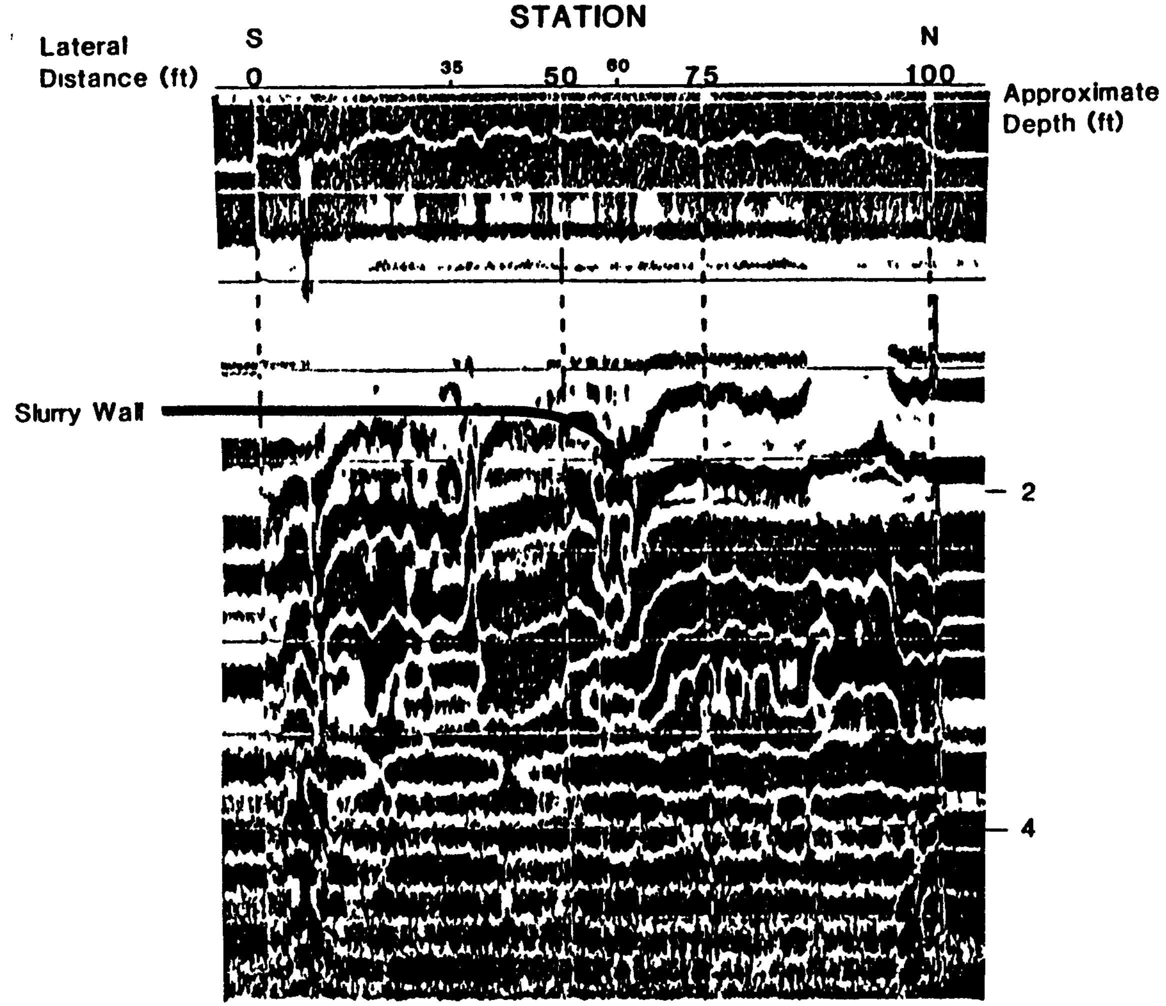

STATION
N
S
0
5
10
15
20
25
Lateral
Distance (ft)
Surface
Slurry
Wall ?
Approximate
Depth (ft)
2
4

Line 4N



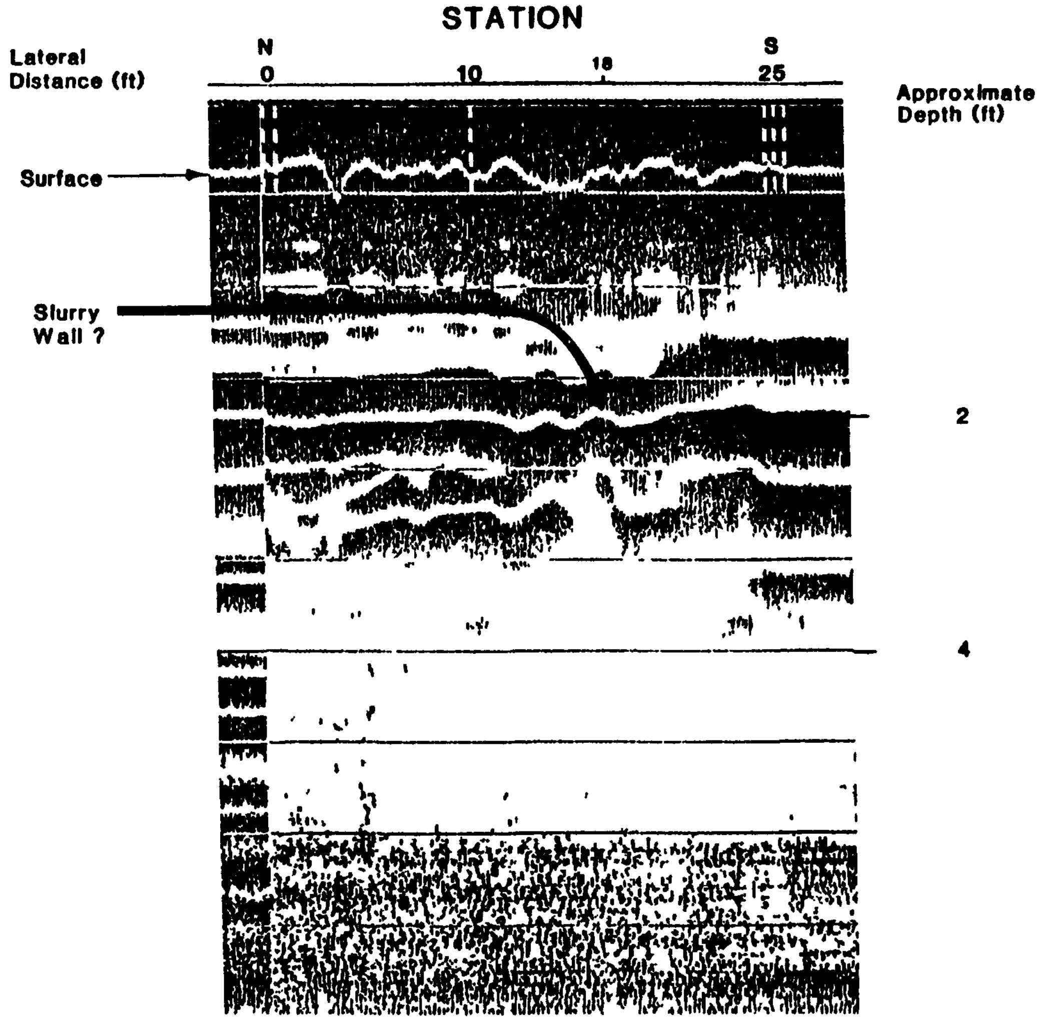
Line 5N

FIGURE 11



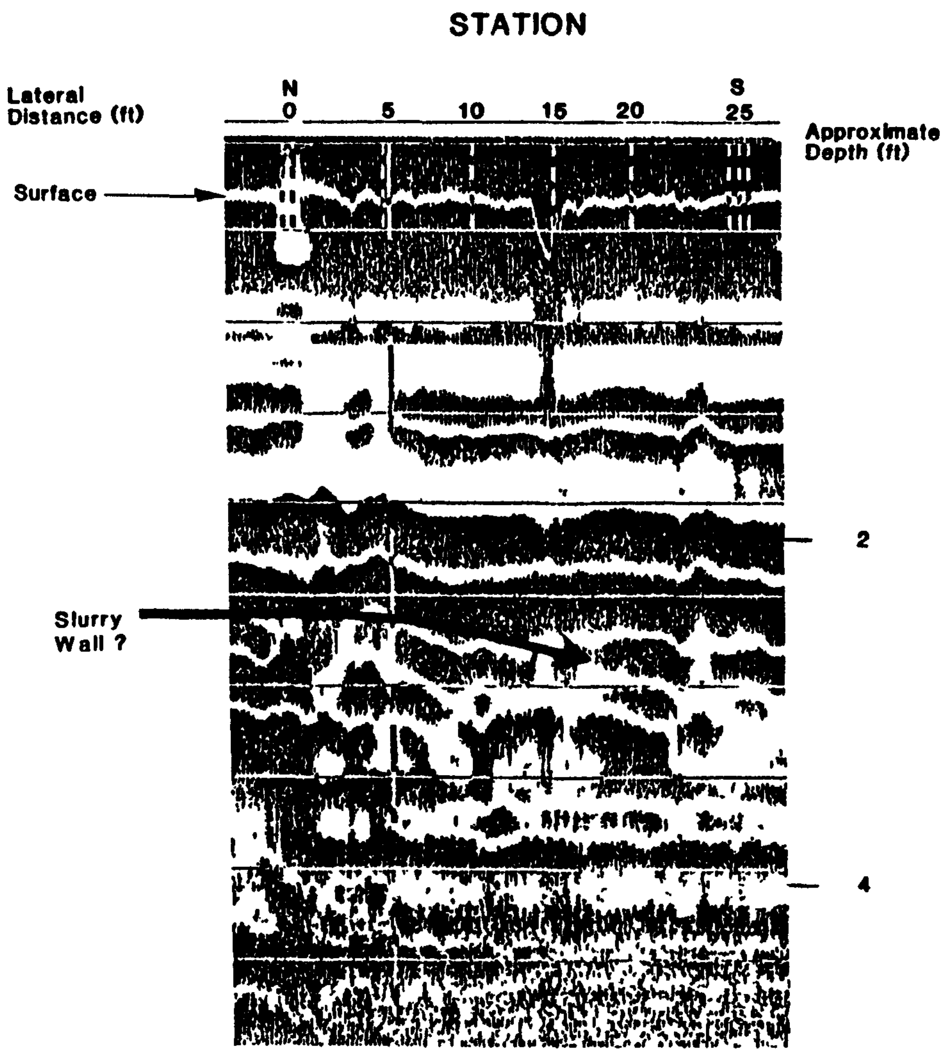
Line 5AN

FIGURE 1?

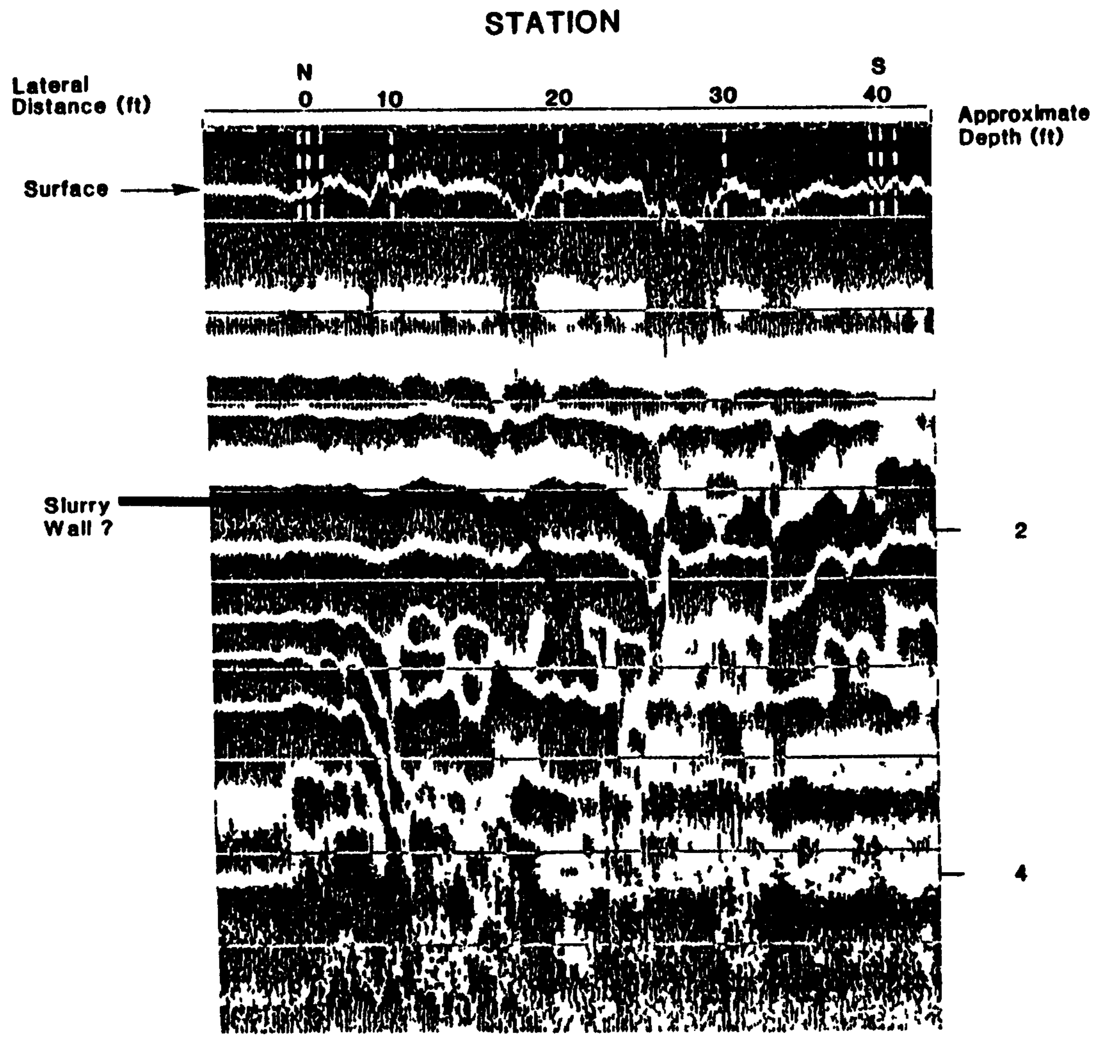


Line 6N

FIGURE 13


STATION
Lateral
Distance (ft)
N
0
5
10
15
20
S
25
Approximate
Depth (ft)
Surface
Slurry
Wall ?
2
4

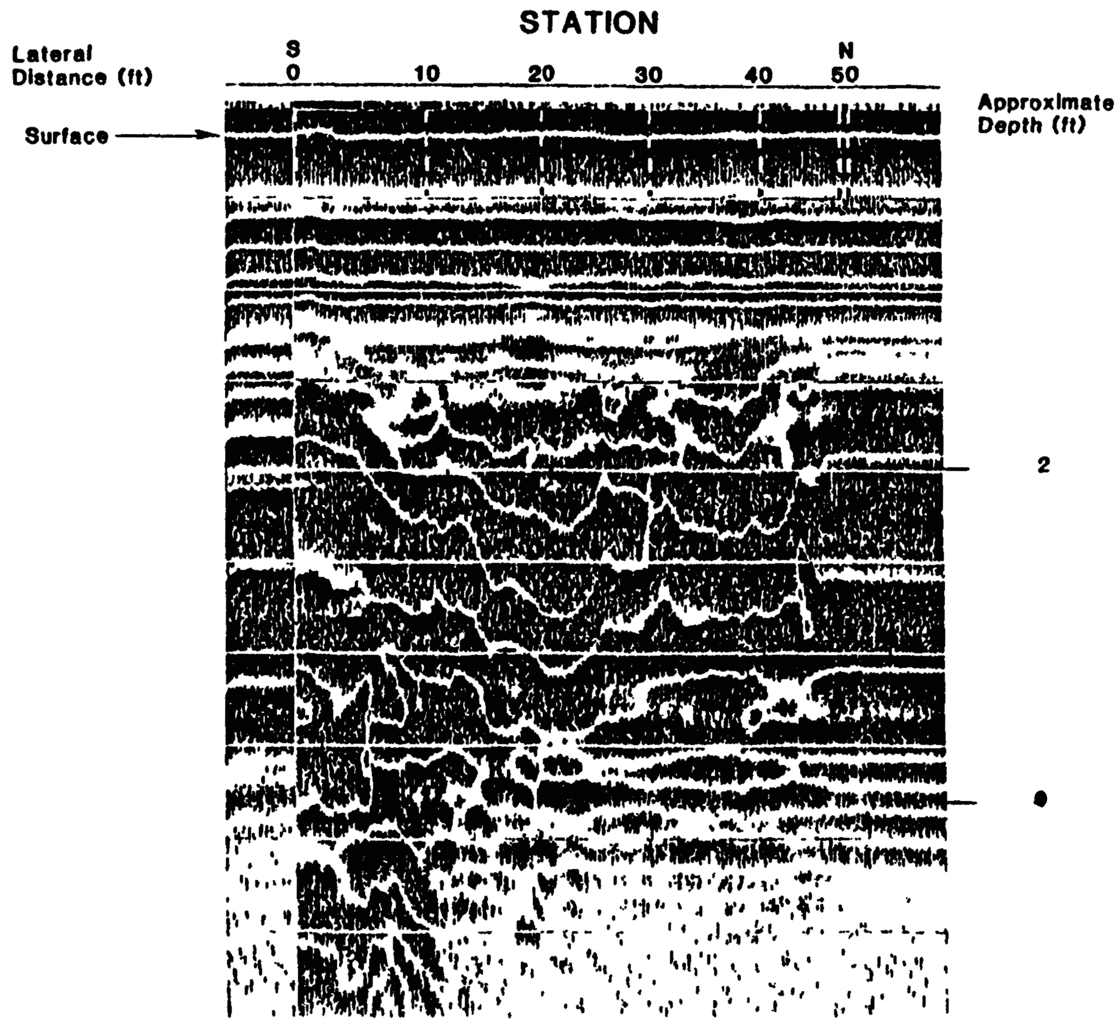
Line 7N



Line 8N

FIGURE 15

APPENDIX B
Uninterpreted GPR Profiles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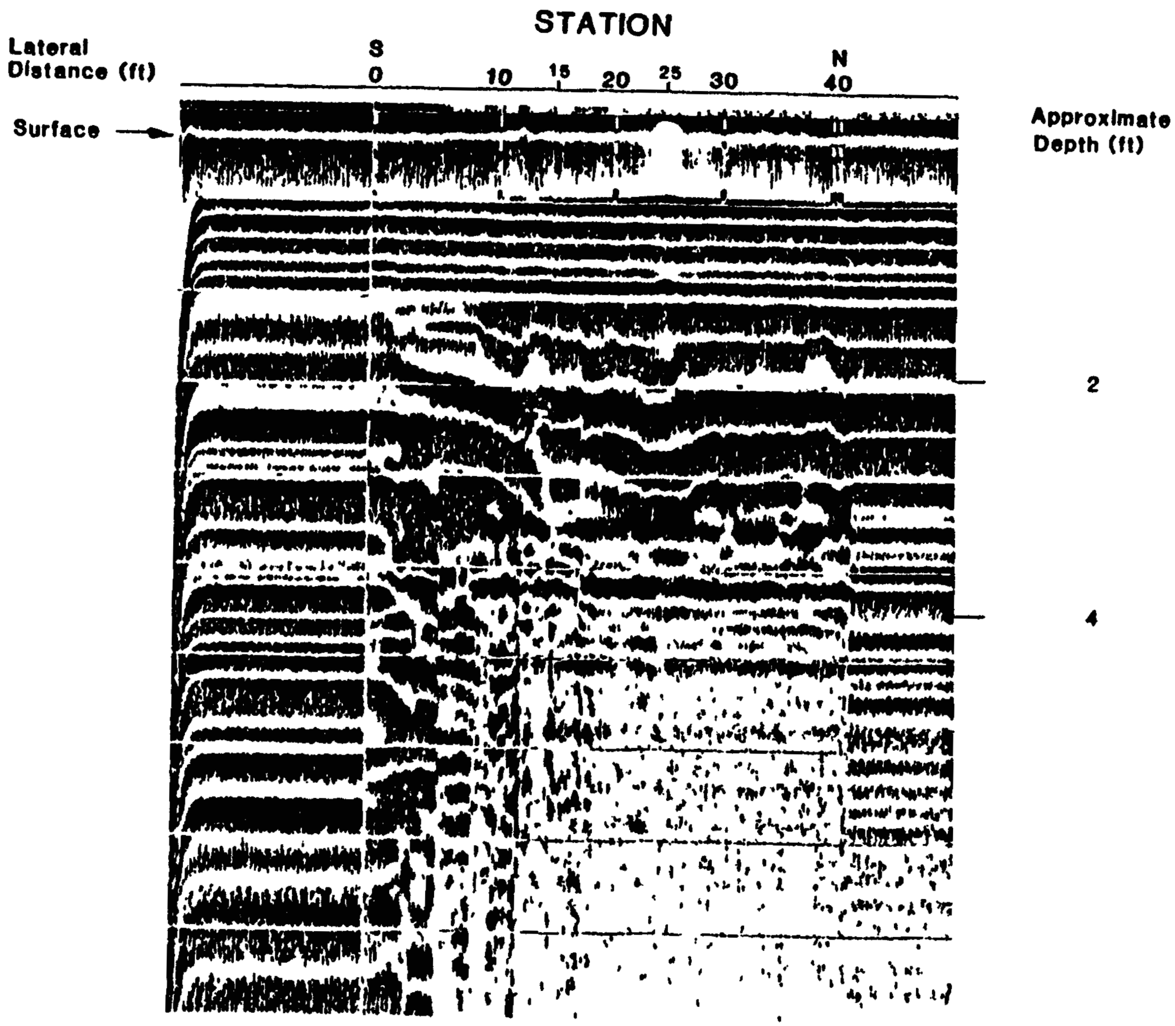
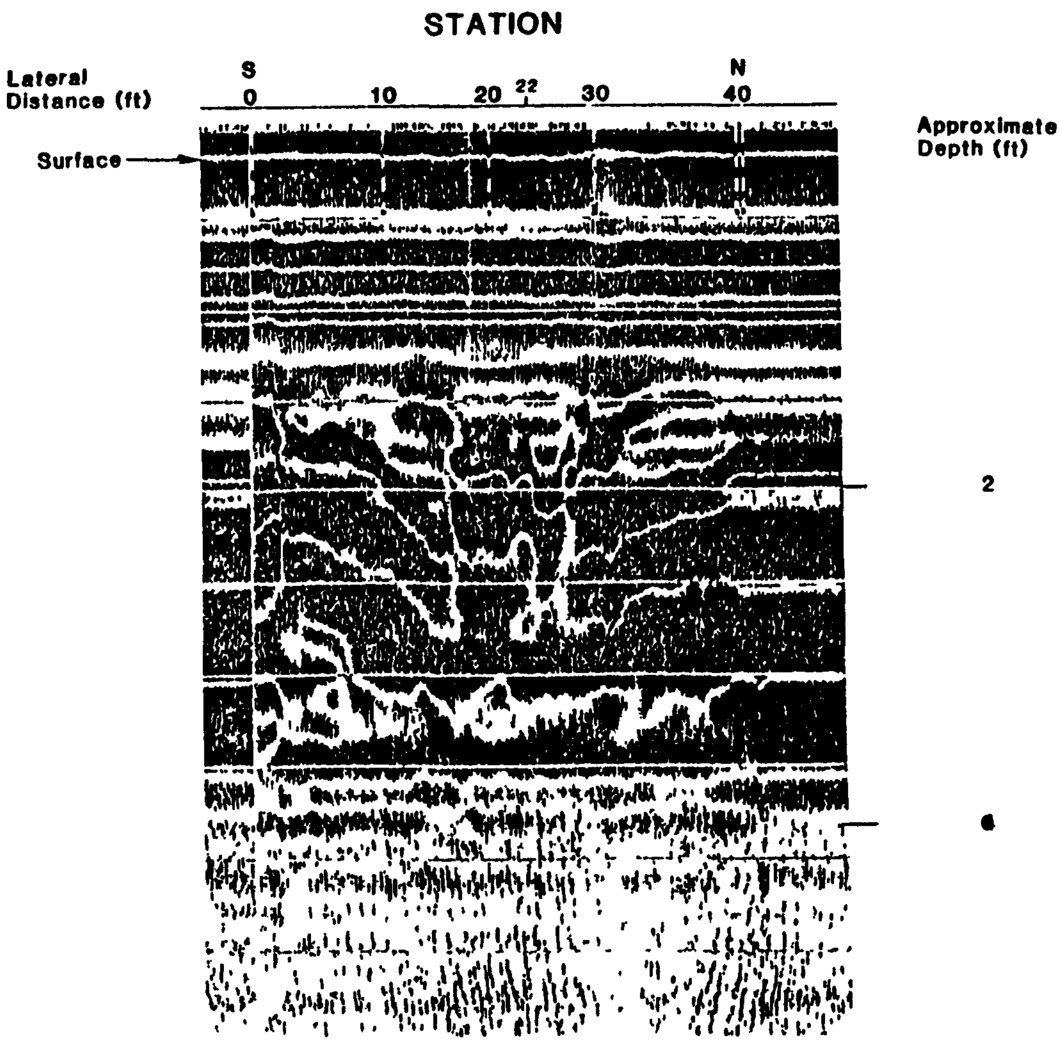
Distance (ft)
S
0
10
20
30
40
50
N
Surface
Approximate
Depth (ft)
2

Line 1S

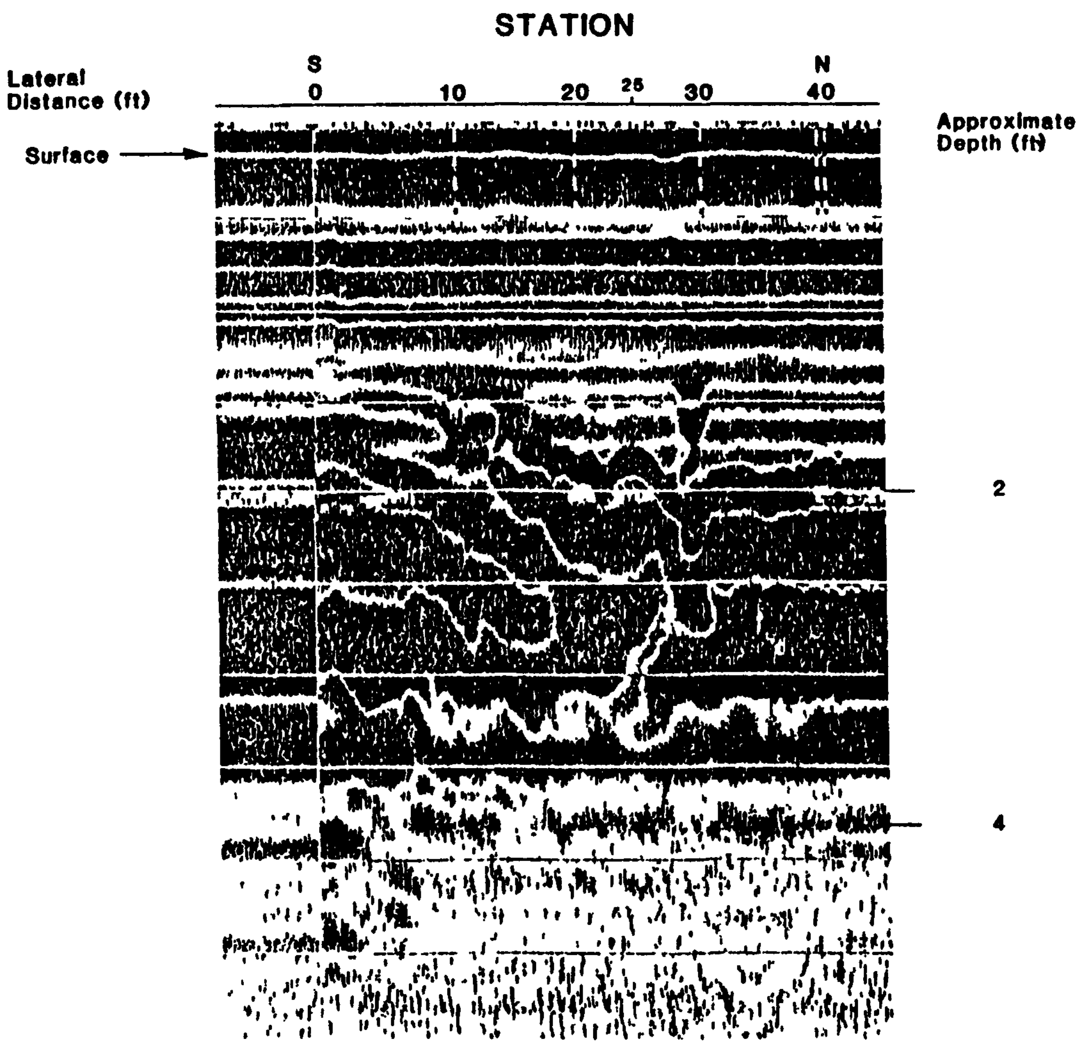


Line 2S

FIGURE 17

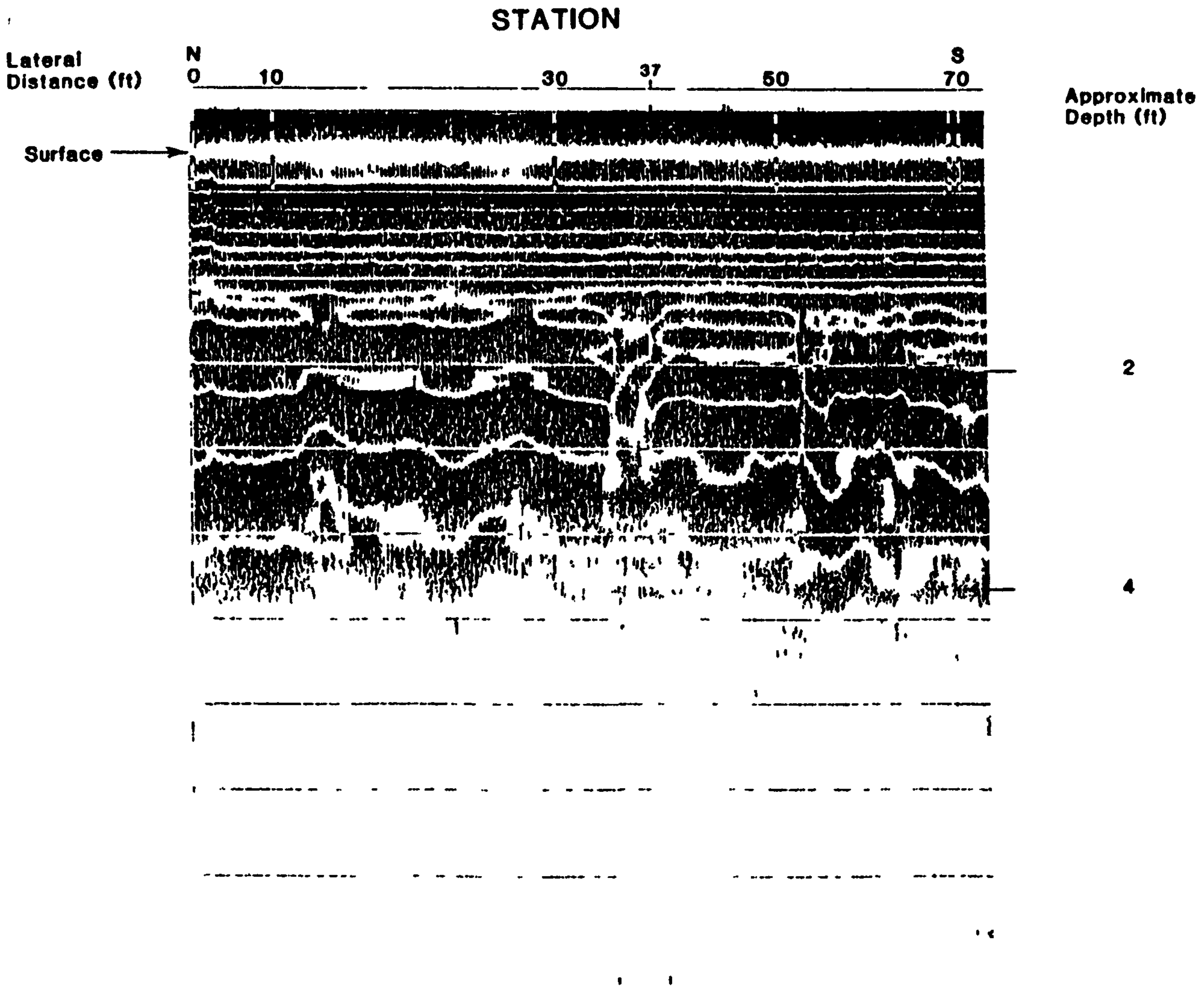

STATION
Lateral Distance (ft)
S
0
10
20
22
30
N
40
Surface
Approximate Depth (ft)
2
4

Line 3S



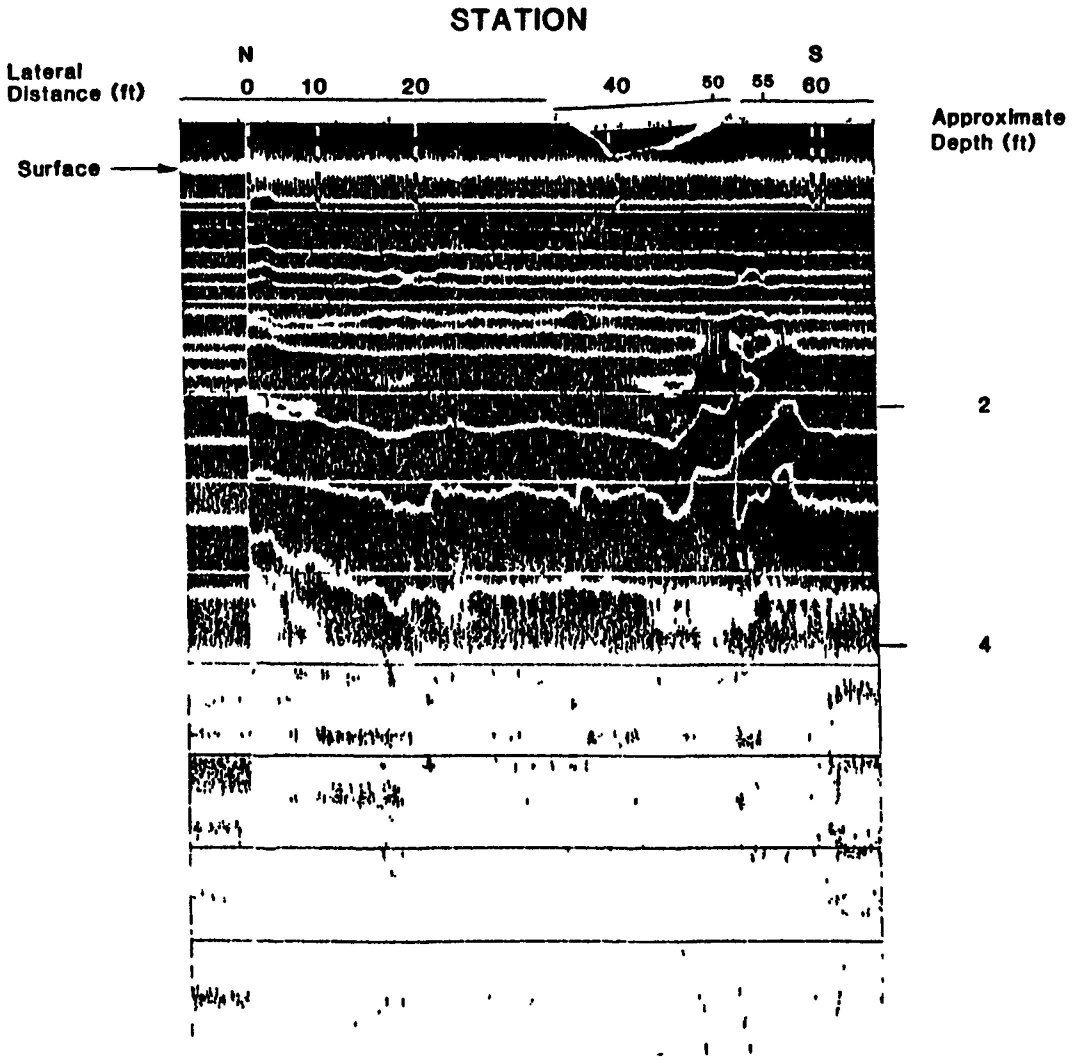
Line 4S

FIGURE 19

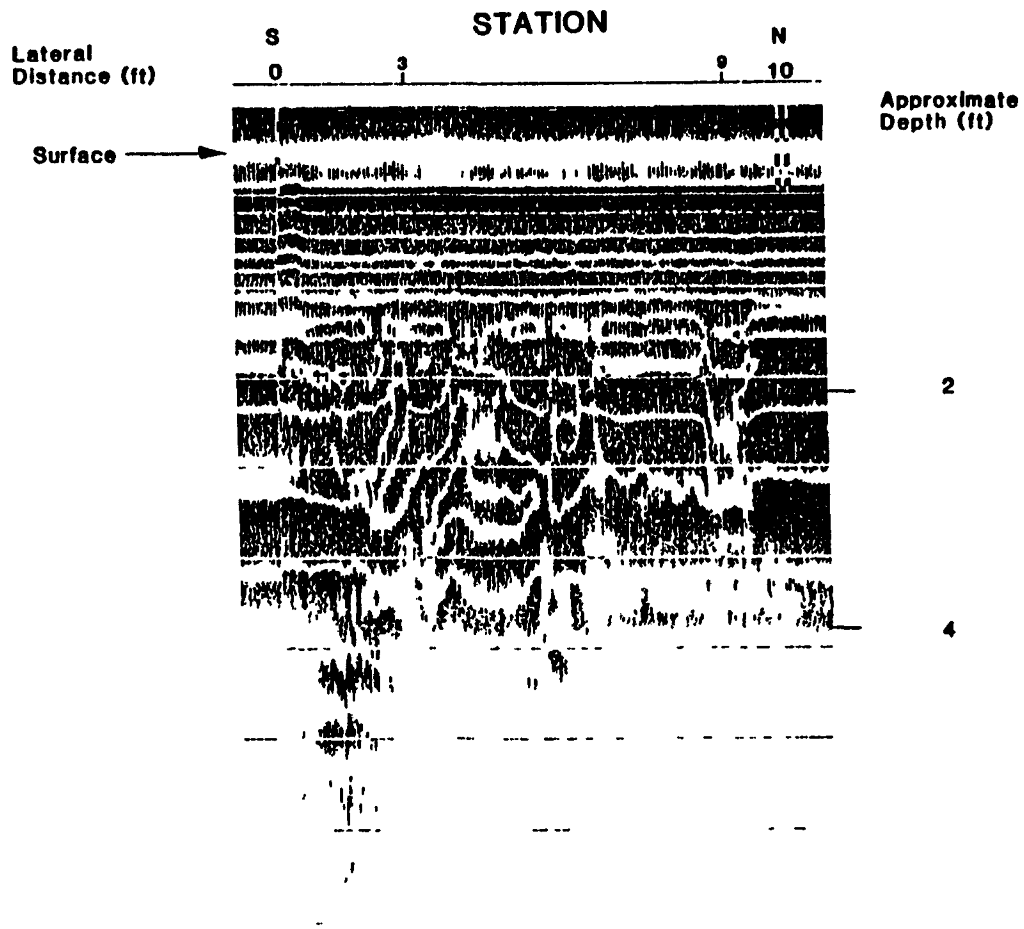


Line 1N

FIGURE 2?

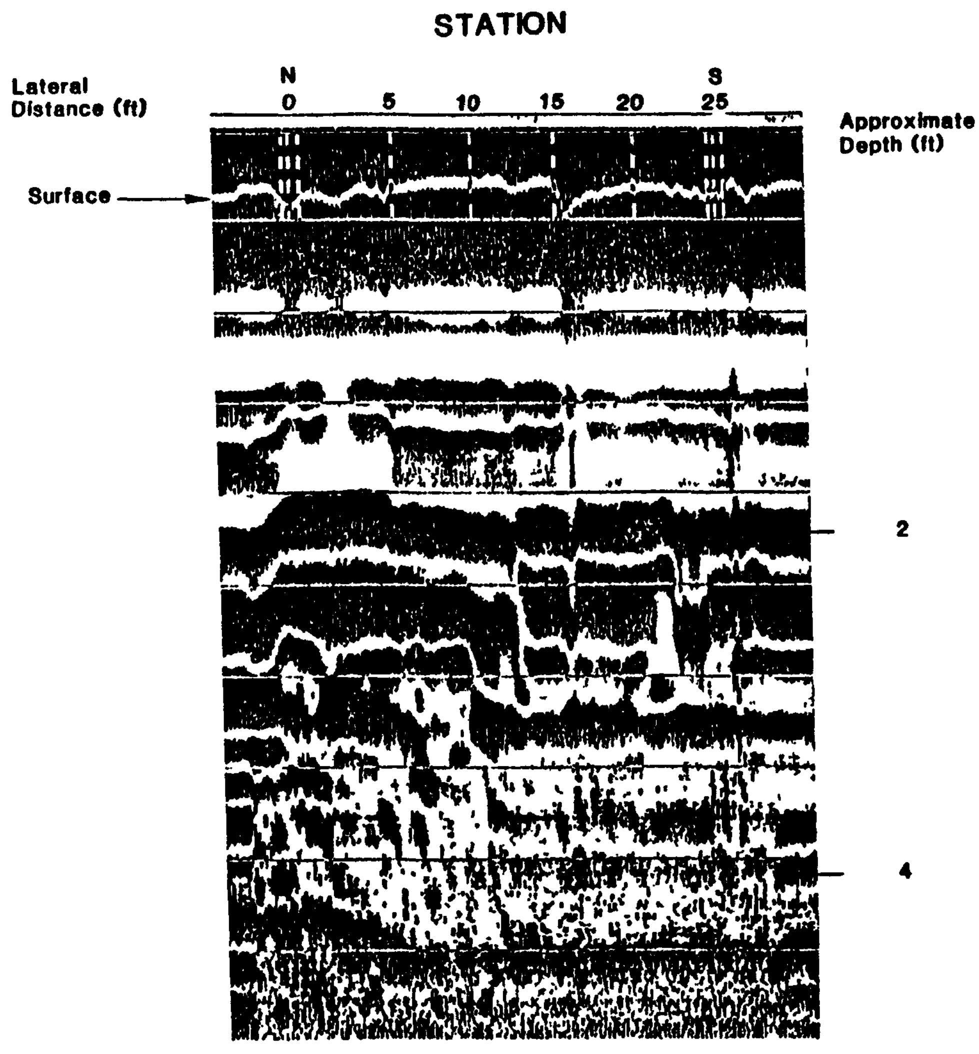

STATION
N
S
Lateral Distance (ft)
0
10
20
40
50
55
60
Surface
Approximate Depth (ft)
2
4

Line 2N



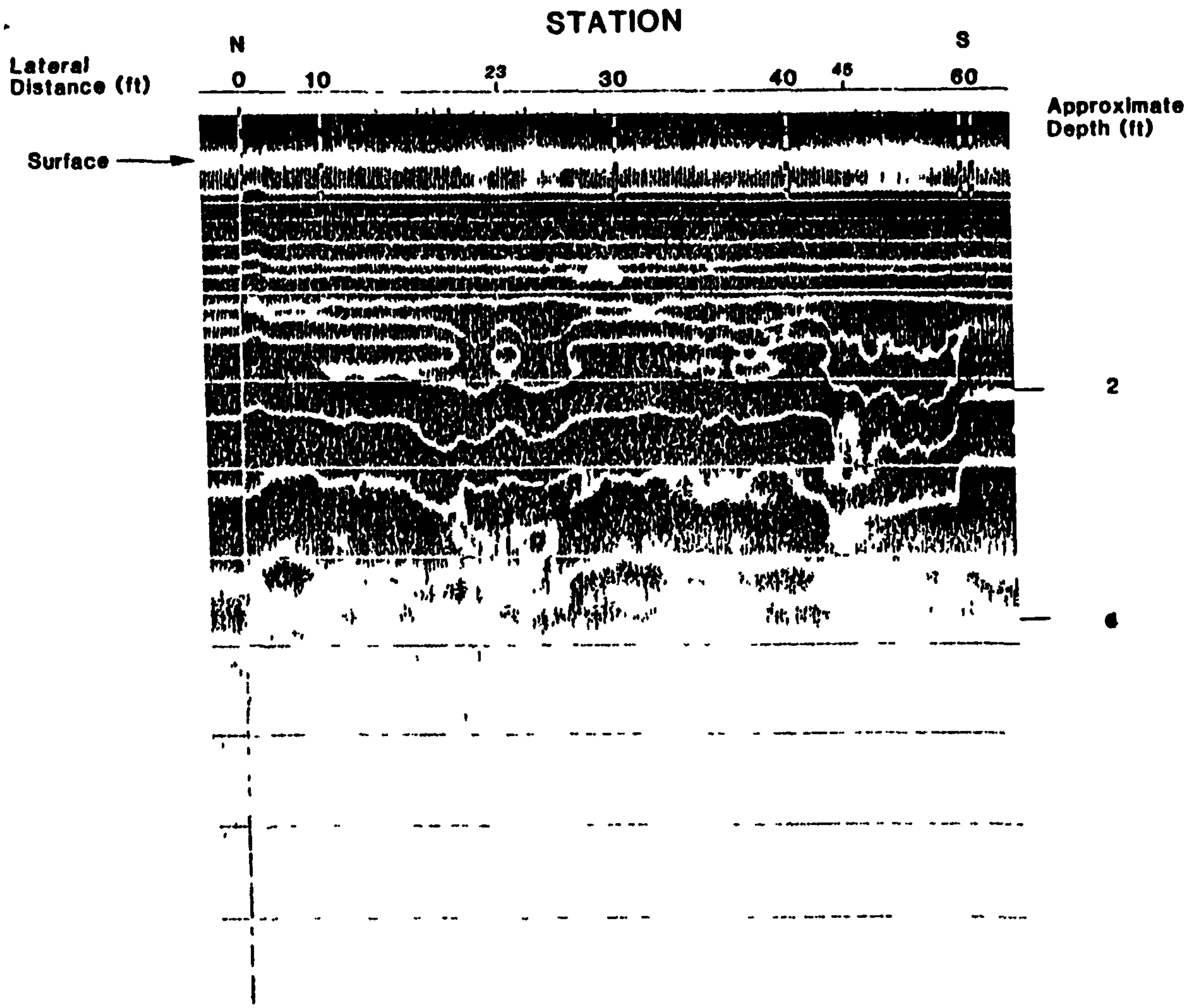
Line 3N

FIGURE 22



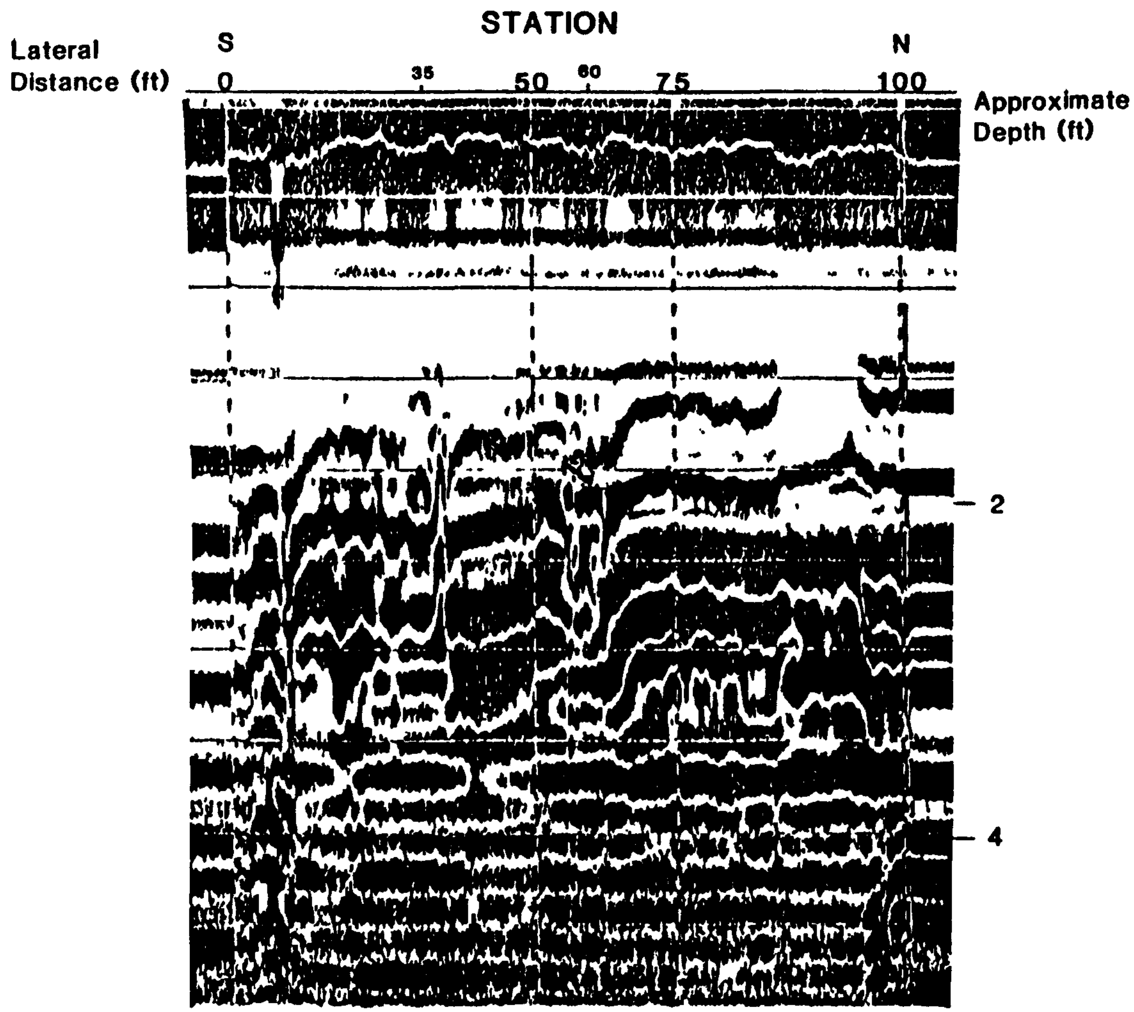
Line 4N

FIGURE 23

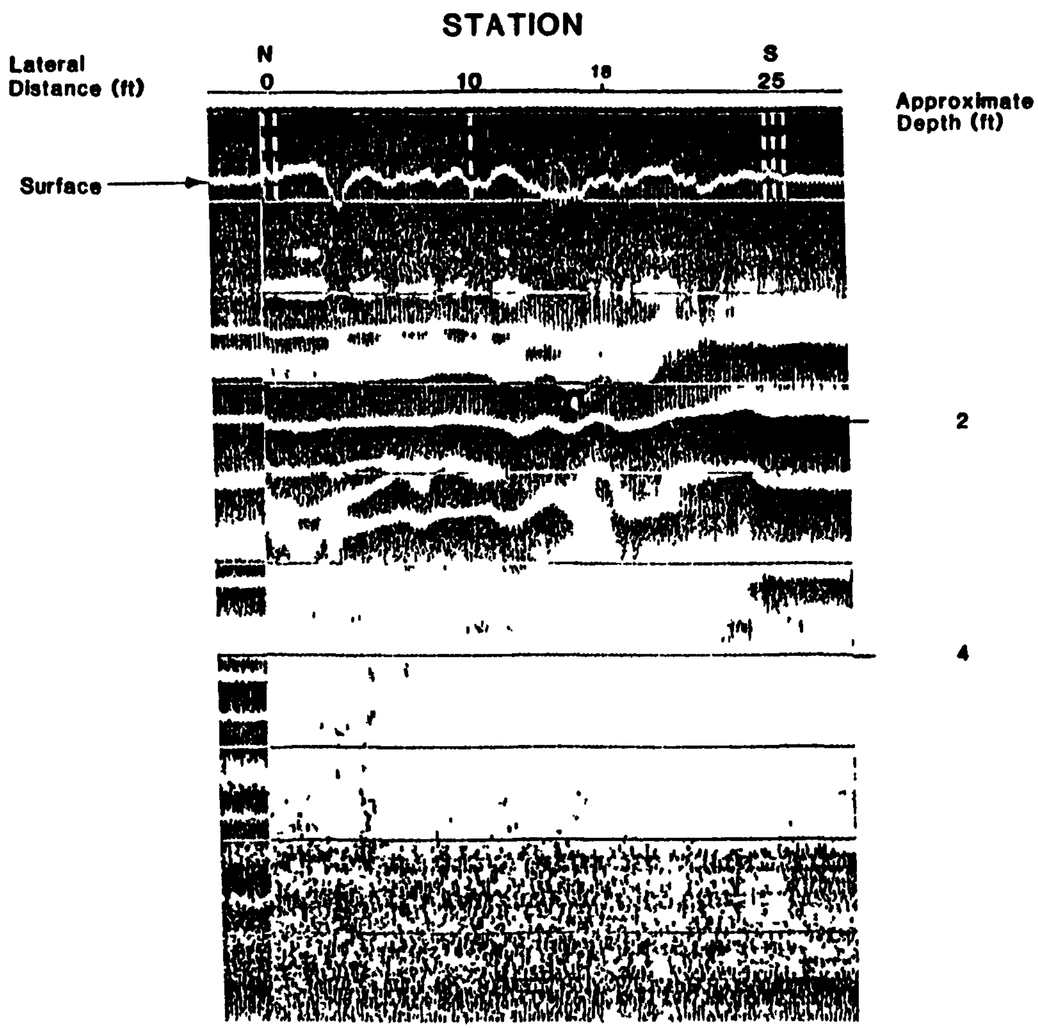


Line 5N

FIGURE 24

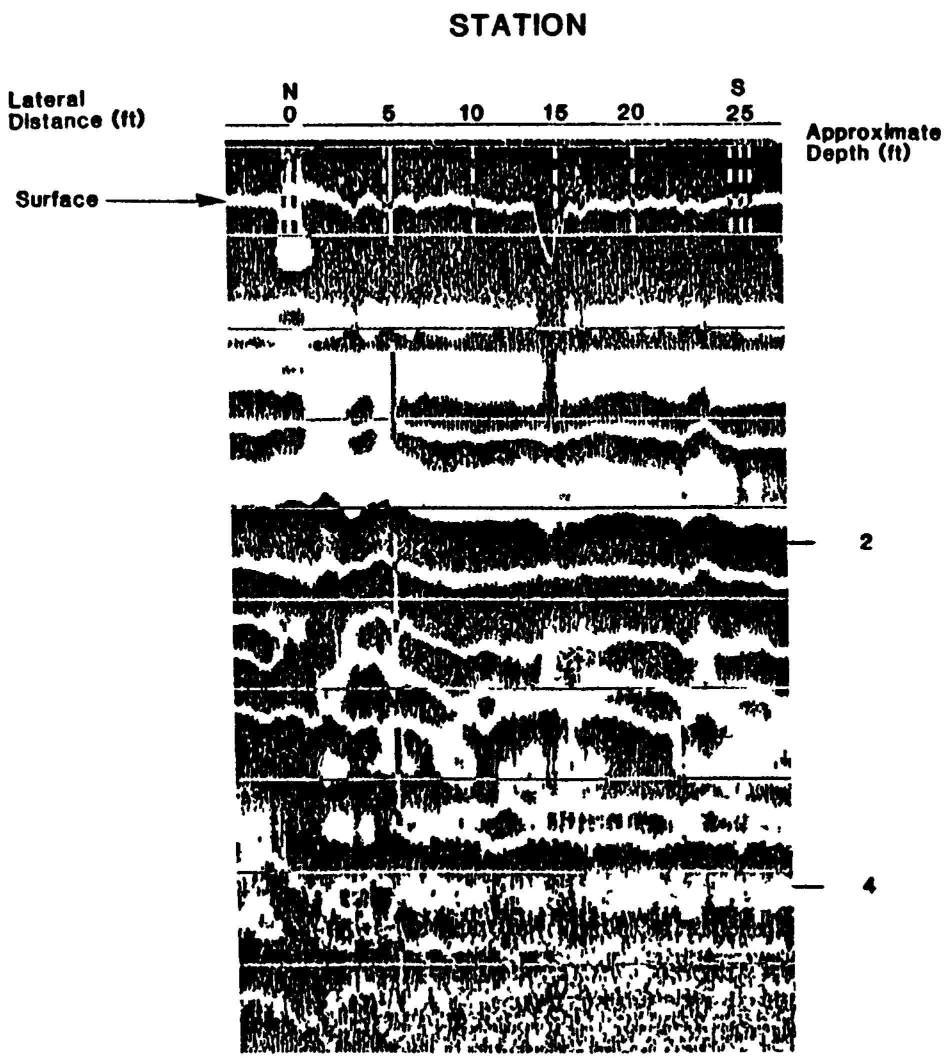

STATION
S
N
Lateral
Distance (ft)
0
35
50
60
75
100
Approximate
Depth (ft)
2
4

Line 5AN



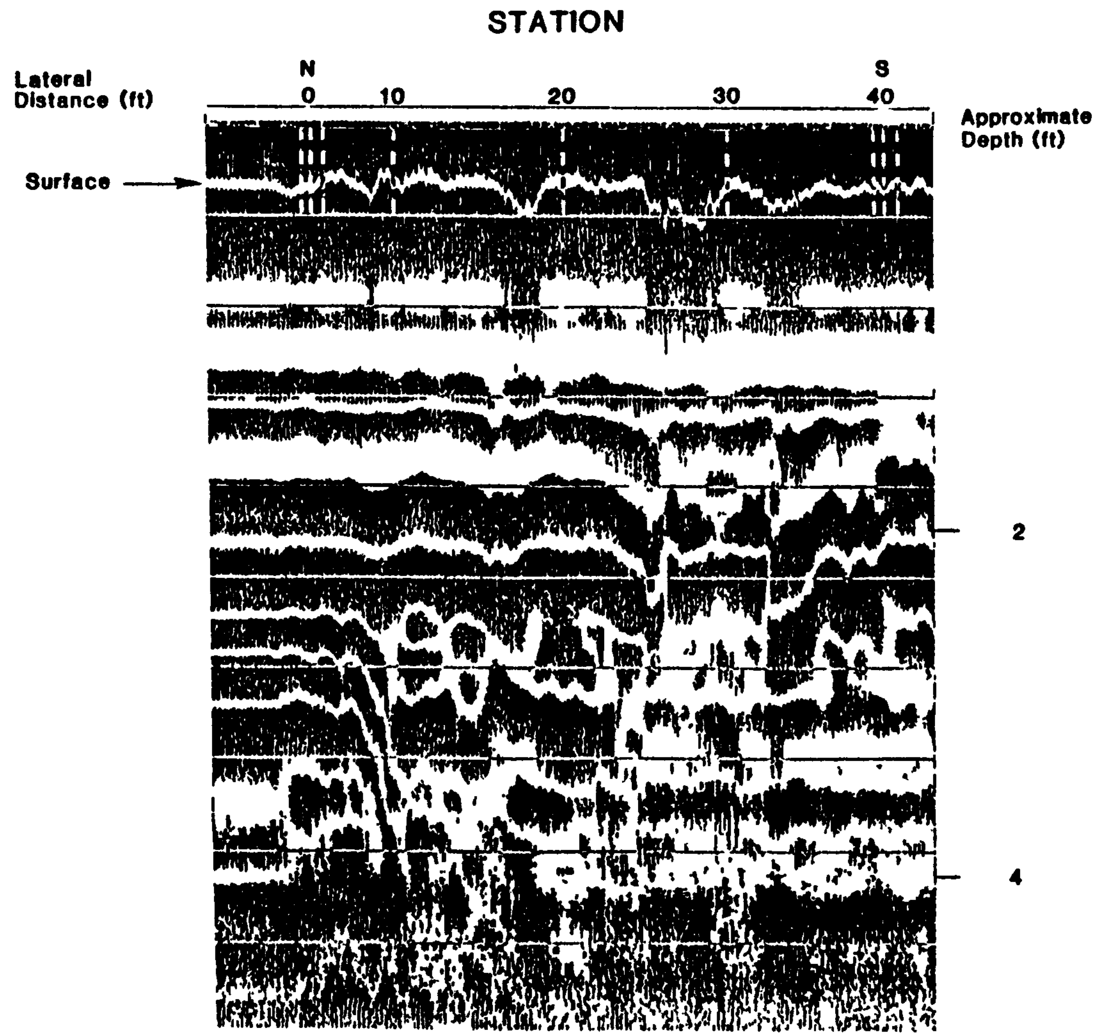
Line 6N

FIGURE 26



Line 7N

FIGURE 27



Line 8N

FIGURE 28

APPENDIX C
Operating Landfill Extension Site Plan Blueprints

SHEET 2	Plant Layout
SHEET 3	Site Plan
SHEET 4	Boring Logs
SHEET 5	Borings Logs
SHEET 6	Detail Sheet